Using Formative Assessment and Metacognition to Improve Student Achievement

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Achievement gains generated by using formative assessment were among the largest ever reported for education interventions.

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Abstract *This paper describes a multistep Enhanced Formative Assessment Program (EFAP) that features a Self-Regulated Learning (SRL) component. The program, which teaches students to become more effective learners, has been applied in a wide range of academic disciplines. In this paper we report on how the EFAP-SRL model can be applied to the area of developmental mathematics. In a 3-year series of studies, EFAP-SRL students enrolled in associate degree developmental mathematics courses consistently earned higher pass rates in the course as well as higher pass rates on the mathematics portion of the ACT. In addition, there is some evidence that program students transferred this learning into subsequent college-level mathematics courses.*

The academic readiness of incoming college students is a major concern. For example, Tritelli (2003) reports that fewer than half of the students who enter college directly from high school complete even a minimally defined college preparatory program, and, as a result, more than half of these entering students are required to take at least one developmental course. This lack of readiness is further reflected in the low level of success in completing the required sequence of developmental courses (Bailey, 2009; Hoyt & Sorenson, 2001; Levin & Calcagno, 2008). Consequently, it is not surprising that only 23% of entering community college students earn an associate degree after 6 years (Brock, 2010). A major stumbling block and gatekeeper area has been mathematics; therefore, this study illustrates the implementation and research of the EFAP-SRL model in developmental mathematics.

As research on academic underpreparedness becomes more abundant, the situation becomes increasingly grim. A recent report from the American Diploma Project (Achieve, 2010) found that 81% of twelfth graders were rated as having below a basic level of performance in Algebra I, and 98% of twelfth graders needed preparation in Algebra II. This finding is in keeping with The Strong American Schools report (2008), which found that more than 40% of high school graduates entering two-year colleges require mathematics remediation at a cost of between 1.85 and 2.35 billion dollars annually. Lutzer, Rodi, Kirkman, and Maxwell (2007) found that developmental mathematics courses comprise over half of the mathematics course offerings at many two-year colleges. Furthermore, the Carnegie Foundation (2009) reported between 60% and 70% of developmental mathematics students do not successfully complete the prescribed sequence of required courses. Notably absent from efforts to improve student success is the incorporation of formative assessment to improve student self-regulation and metacognitive skills.

Formative Assessment: A Review of a Powerful Intervention

In a series of landmark review articles, Black and Wiliam (1998a, 1998b, 2009) dramatically highlighted formative assessment's contribution to precollege student learning. They concluded that achievement gains generated by using formative assessment across a range of content domains were among the largest ever reported for education interventions. Notably, the largest gains were realized among low achievers. Black and Wiliam (2009) define effective formative assessment as a process that involves: (a) teachers making adjustments to teaching and learning in response to assessment evidence, (b) students receiving feedback about their learning with advice on what they can do to improve, and (c) students participating in the process through self-assessment.

Definition

The common denominator in this work is that effective formative assessment is an ongoing instructional process that systematically incorporates assessment, as opposed to calling for a particular kind of assessment instrument or test. Heritage (2010) makes this a central theme in her report when she writes about the risk of

> losing the promise of formative assessment for teaching and learning. The core problem lies in the false, but none-the-less widespread, assumption that formative assessment is a particular kind of measurement instrument rather than a process that is fundamental and indigenous to the practice of teaching and learning. (p.1)

She also goes on to conclude that despite its demonstrated effectiveness across a wide variety of disciplines, formative assessment has not been effectively incorporated into college-level instruction.

Feedback and Its Relationship to Formative Assessment

The literature on formative assessment suggests that feedback is a key element in assisting the learning process for both instructors and students (Hattie & Timperley, 2007). Simply put, instructors receive feedback from their classroom assessments and can use this information to make changes in their instructional practices and curricula designs. Instructors can also provide feedback to students about how they can improve their own learning. Students, in turn, are expected to use this feedback to make constructive changes in how they learn (Black & Wiliam, 2009). Subsequently, the formative assessment process is integrated into classroom instruction as an ongoing process and can promote mastery learning and curriculum-based measurement (Fuchs, 1995; Zimmerman & DiBenedetto, 2008).

In this formulation, the formative assessment process not only uses feedback to promote content learning, but it also helps students "learn how to learn." Students begin to understand their intended learning goals, develop the skills to make judgments about their learning in relation to a learning standard or instructional outcome, and implement a variety of strategies to regulate their learning (Heritage, 2010). As such, formative assessment merges with theories of metacognition in general and self-regulation in particular (Nicol & Macfarlane-Dick, 2006). Underscoring the centrality of feedback in the learning process, Hattie and Timperely (2007) reviewed 196 K-12 feedback studies and found a positive mean effect size of 0.79 for achievement measures—an effect greater than students' socioeconomic background and reduced class size. However, they cautioned that the effect size varied widely depending upon the type of feedback that instructors provided for their students. The most significant achievement gains involved having students receive information about a task and how to do it more effectively. Less important types of feedback included praise and punishment.

Within this framework, effectively using formative assessment, with its emphasis on developing "learning to learn" skills, differs from the typical classroom-based assessments used in many college classrooms. Although instructors often give their students an occasional quiz or exam in addition to the midterm and final exams, they typically do not use these assessment opportunities to improve their own instructional approaches and provide students with constructive feedback and suggestions for improving their general learning strategies.

The SRL Component of Formative Assessment

To date, the majority of formative assessment interventions have emphasized content competency to the exclusion of "learning how to learn" or metacognitive, self-regulatory strategies. The EFAP focuses on the idea that formative assessment related to course content is optimized when students' self-regulatory competencies are also explicitly targeted for development during the assessment process. Throughout the formative assessment cycle, students are taught to develop and use self-regulation to better use feedback and subsequently optimize learning (Hudesman, Zimmerman, & Flugman, 2010; Zimmerman, Moylan, Hudesman, White, & Flugman, 2011).

The SRL approach guiding our work is based on models of self-regulated learning developed by Zimmerman (2000, 2002, 2006) and Grant (2003; Grant & Green, 2001). It is a psycho-educational model characterized by continuous feedback cycles. In this approach, each feedback cycle is broken down into three main phases. The first is a planning phase, in which students conduct academic task analyses, choose strategies that best address their specific learning challenge, set identifiable goals, and make self-efficacy and self-evaluation judgments to assess the accuracy of their level of understanding and content mastery. Next is a practice phase, in which students implement their plans, monitor their progress, and make real-time adjustments to their learning plans. This is followed by an evaluation phase, in which students assess the strategies' effectiveness based on teacher feedback, build on the successful strategies, and/or modify or replace less effective ones. The students' responses from the evaluation phase become the basis for subsequent, iterative planning phases in ongoing SRL cycles.

> *Students begin to understand that learning is directly related to experimenting with different strategies.*

The SRL intervention derives much success from its cyclical nature; each time students complete a cycle, they acquire more feedback and therefore, come closer to achieving their learning goals. Students begin to understand that learning is directly related to experimenting with different strategies, a notable shift from the more common notion that achievement is simply a function of innate ability or some other external factor (Zimmerman, 2002).

The power of SRL competence is highlighted in Zimmerman and Bandura's classic 1994 study in social learning theory. They demonstrated that students' SRL skill levels are more highly correlated with their college grade point average than their scores on standardized tests such as the SAT.

The Application of the EFAP-SRL: Developmental Mathematics Examples

The four studies described following represent a portion of our ongoing research on an EFAP-SRL Program which has been iteratively developed, implemented, and refined. The EFAP-SRL Program focuses on improving the students' academic performance through the development of their metacognitive skills. The program includes the use of a series of specially formatted assessments that are followed by self-reflection and revision forms, as well as classroom exercises that emphasize the constructive use of feedback. The model is not content-specific and can be implemented in a wide variety of courses; for example, the EFAP-SRL Program has been applied to entry-level college mathematics courses and other STEM disciplines such as electromechanical engineering technology (Blank, Hudesman, Morton, Armstrong, Moylan, & White, 2007; Hudesman, Crosby, Ziehmke, Everson, Isaac, Flugman, & Zimmerman, in press; Hudesman, Zimmerman, & Flugman, 2005, 2010; Zimmerman, Moylan, Hudesman, White, & Flugman, 2011). Additionally, in one program the EFAP-SRL program was applied to 12 different disciplines across five schools. Although the following studies were carried out under a variety of programmatic and experimental conditions, they are reported in one paper given the consistency of positive results that, when taken as a whole, support the value of the EFAP-SRL program in assisting students with their developmental mathematics performance.

Operational Features of the EFAP-SRL Model

The model consists of five major components that are designed to effectively deliver a range of different course material.

1. Instructors administer specially constructed quizzes that assess both the students' academic content and SRL competencies.
2. Instructors review and grade the quizzes to provide feedback about both the content and SRL competencies that students struggled with; instructors also use quiz feedback to adjust their instruction.
3. Students complete a specially constructed self-reflection and revision form for each incorrectly

answered quiz question, which affords them an opportunity to reflect on and then improve both their academic content and SRL processes that were incorrectly applied.

4. Instructors review the completed self-reflection forms to determine the degree to which students have mastered the appropriate academic content and SRL skills. Based on the instructor's evaluation of their work, students can earn up to the total value of the original quiz question. Based on the reflection form data, instructors also have an additional opportunity to make changes to the academic content and SRL topics to be covered in upcoming lessons.
5. Instructors use the feedback provided by the quiz and self-reflection form as the basis for ongoing class discussions and exercises, during which students discuss the relationship between their academic content and SRL skills. The students develop plans to improve these areas.

Research Questions

For the four studies reported here, the general research question was whether the introduction of an EFAP program that features SRL can improve the mathematics performance of students enrolled in developmental mathematics as measured by course pass rates and pass rates on the mathematics portion of the ACT.

In addition, there were four derivative research questions:

1. Are students enrolled in EFAP-SRL classes more likely to pass a developmental mathematics course than students enrolled in similar courses that did not implement the EFAP?
2. Are students enrolled in EFAP-SRL developmental mathematics classes more likely to pass a postcourse administration of the COMPASS portion of the ACT than students enrolled in comparison sections of the course?
3. Are students enrolled in EFAP-SRL developmental mathematics classes more likely to enroll in a subsequent college-level mathematics course than students enrolled in comparison sections of developmental mathematics?
4. Are students enrolled in EFAP-SRL developmental mathematics classes more likely to succeed in a subsequent college-level mathematics course than students enrolled in comparison sections of developmental mathematics?

Method

The following section describes the use of the EFAP-SRL program as it was implemented at an urban college of technology. The program was applied in the same developmental mathematics course during various semesters over a 3-year period.

Participants and Design

Two studies were conducted during summer sessions (S1 in year 2005 and S2 in years 2008 & 2009); two more were conducted during the academic year (AY1 in year 2005 and AY2 in years 2006 - 2008). In each of the four studies, we compared the academic progress of students enrolled in EFAP-SRL developmental mathematics classes with the academic progress of students enrolled in other comparable sections of the same course. However, each study was conducted under different experimental conditions.

The site for all of the studies was an urban college of technology with an enrollment of more than 15,000 students from over 100 countries. Typically, students attending the college have reflected similar demographics: almost 90% from minority groups; 53% female, and 47% male; 49% first in their families to attend college; and more than one-third required to enroll in developmental mathematics courses (T. Cummings, personal communication, 2011).

All of the EFAP-SRL program instructors attended a training session.

Assignment of Students to Program Conditions

All students entering the college were required to take the prealgebra and algebra portions of the COMPASS, developed by ACT (1997), which is used as a placement test. After taking this placement test, the students reviewed their test results with their academic advisor. Any student who did not achieve a minimum college-designated cut score (which varied from 27-35 in prealgebra and 27-30 in algebra) was required to enroll in a noncredit developmental mathematics course. In the programs described, the students' assignment to a particular section of either the EFAP-SRL or comparison group developmental mathematics course was made by the academic advisor based on the individual student's scheduling situation and without any input from the EFAP-SRL Program staff.

There were several additional attempts to further eliminate any bias in the assignment of students to either the EFAP-SRL or comparison group sections. In one study (AY2), we were able to randomly assign the entire student cohort to either the EFAP-SRL or comparison group sections of developmental mathematics.

Furthermore, in the AY2 and the S2 studies, we were able to compare mean precourse COMPASS scores for the EFAP-SRL and control/comparison group students. All of the prescores were found to be equivalent for the students assigned to the EFAP-SRL and the comparison group sections.

The Selection of Program Instructors

EFAP-SRL instructors were chosen from a group of voluntary participants. Depending upon the study, the comparison group consisted of instructors who taught the same course at the same time slot, that is, during the summer session or during the academic year. In other studies, the comparison group consisted of all the day-session instructors who taught developmental mathematics that semester. In one study (AY2), the control group instructors were volunteers who taught the course at the same time and agreed to give the same periodic examinations to their students.

Instructor training and program fidelity. All of the EFAP-SRL program instructors attended a training session that involved discussions and workshops on the theory and practice of EFAP-SRL. During the semester, instructors were observed in the classroom by the program staff using a checklist of EFAP-SRL activities; see Appendix C (p. 31; Zimmerman et al., 2011) for a copy of the observation form. It should be noted that the observation items focused on instructor strategies that would increase the students' use of "learning how to learn" strategies and not on the actual mathematics content. This form was designed so that observers could determine the frequency of SRL-related instructional behaviors during a 1-hour session. The observers indicated the frequency of SRL-related behaviors on a five-point scale that ranged from (1) *never* to (5) *very often*.

Instructor support. The observation form was developed to support the SRL instructors. After each class visit, the observers met with the instructor to review any areas where the instructor's use of specific SRL behaviors needed to be built up. The content of the observation checklist remained fairly standard throughout the different studies. In most of the studies there was no attempt to use the form in the comparison group sections. However, in one study (AY2), we used the form as a measure of program fidelity. In this study, two SRL staffers observed both SRL and control group classes three times during the semester. The experience levels of instructors in both the EFAP-SRL and comparison groups varied widely.

A Description of the Four EFAP-SRL Implementations

Table 1 (p. 6) summarizes the conditions and sample sizes of the four EFAP-SRL studies. There were a total of 10 EFAP sections with an enrollment of 253 students, and a total of 42 comparison sections with an enrollment of 945 students.

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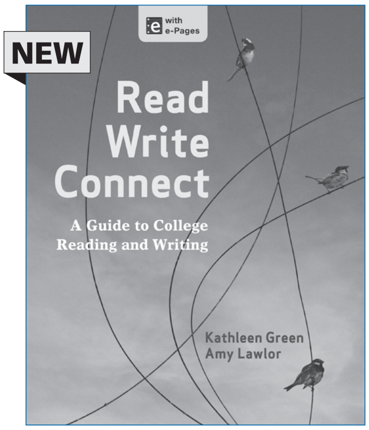

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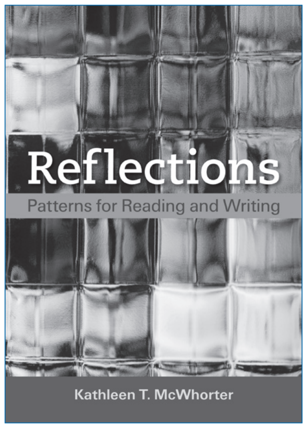

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The two summer implementations. All summer session courses were scheduled to meet four times a week for 6 weeks, totaling 24 sessions. Tutoring services were made available to all of the students enrolled in the EFAP-SRL and comparison sections of developmental mathematics. It is worth noting that traditionally, summer session students have an advantage over those students who take developmental mathematics courses during the academic year since summer session students only need to focus their efforts on passing one course rather than managing a number of other courses simultaneously.

The two academic-year implementations. All academic-year courses met twice a week over a 15-week semester. As mentioned, students in these academic-year developmental mathematics classes were also enrolled in other developmental and/or college-level course work.

It should be stressed that all developmental mathematics courses were required to cover the same course content, sequence of topics, and number of classroom hours. Furthermore, the final examinations were mandated by the college's mathematics department and were standard across all sections.

Materials and Procedures

The focus of the EFAP-SRL Program was to introduce students to EFAP-SRL procedures that would enhance their metacognitive abilities, and, in turn, improve their mathematics performance. This approach contrasts with the traditional instructional method that focuses exclusively on teaching mathematics content strategies, for example, the steps needed to solve a quadratic equation by factoring. By contrast, the EFAP-SRL Program focuses on teaching students to better plan, practice, and evaluate their "learning how to learn" strategies, in addition to traditional academic content strategies. By practicing this model students also have the potential to transfer the skills they learned in the program to subsequent mathematics classes. Additional examples of the EFAP-SRL model are described in the section on classroom discussions and exercises.

Mathematics quizzes. Students enrolled in the EFAP-SRL course sections completed specially formatted quizzes that were administered at least once a week during the fall and spring semesters and up to twice a week during the summer session. Each quiz consisted of five mathematics questions and required no more than 15 minutes to administer. For each of the five mathematics questions, students were required to make several metacognitive judgments. For example, when completing the top portion of the quiz, students were asked to predict their quiz grade and to enter the amount of time they spent preparing for the quiz. Once they started the quiz, students were asked to read each question, but before answering it, they were asked to make a self-efficacy judgment to indicate how confident they were that they could correctly solve the problem. After attempting to solve the problem, students were asked to make a second self-evaluation judgment, indicating how confident they were that they had correctly solved the problem. A quiz containing sample mathematics questions and formatted with the self-efficacy and self-evaluation judgments is illustrated in Appendix A.

Scoring and providing feedback. Reviewing the students' mathematics content and SRL judgments, instructors assembled information that they could use to provide feedback for students. Then, after determining the areas students struggled with the most, instructors could modify their instruction.

The quiz also provided the instructors with information about the relationship between the students' quiz scores (i.e., content competencies) and their time management, self-efficacy, and self-evaluation judgments (i.e., SRL competencies). This information is important because struggling students frequently make more optimistic predictions about their knowledge than are warranted by their actual quiz scores, indicating that they often do not recognize the difference between "what they think they know" and "what they don't know" (Tobias & Everson, 2002). As a result of this false belief, these students do not feel any need to remedy the situation by changing their "learning how to learn" behaviors. Therefore, they continue a destructive cycle of poor planning and poor academic outcomes. Being able to provide students with ongoing feedback about the relationship between their actual performance (i.e., quiz score) and their predicted scores and also the relationship between their preparation time and their self-efficacy and self-evaluations judgments is critical to improving the students' mathematics and metacognitive skill sets.

The SRL math self-reflection and mastery learning form. For each incorrectly answered quiz question, students were expected to complete a separate self-reflection and mastery learning form. This form was designed to further assist students in assessing the relationship between their content knowledge and their ability to use critical SRL tools. In the first section of this form, students were asked to: (a) compare their predicted quiz score and their actual quiz score and explain any significant discrepancy; (b) evaluate the accuracy of their academic confidence judgments (i.e., their self-efficacy and self-evaluation judgments) and compare them to their actual quiz score; and (c) based on the instructor's written feedback and/or prior class discussions, indicate which of the mathematics strategies were incorrectly applied when they attempted to solve the problem.

In the second section of the EFAP-SRL Reflection Form, students again solved the original problem and included a *written* description of the specific mathematics strategies and procedures involved in their work. Students were also required to use these same mathematics strategies to solve a similar problem. A sample self-reflection form is illustrated in Appendix B (Blank et al., 2007).

Scoring the self-reflection and mastery learning form. The EFAP-SRL Reflection and Mastery

Table 1

A Description of the Four EFAP-SRL Implementations That Were Conducted at an Urban College of Technology

Program			Groups	
Designation	Session	(*N*)	SRL sections (*n*)	Comparison/control sections (*n*)
S*1	Summer 2005	(189)	2 (47)	6 (142)
S*2	Summers 2008 & 2009	(526)	2 (43)	25 (483)
AY**1	Fall 2005	(284)	3 (62)	8 (222)
AY**2	Fall & Spring 2006-2008	(199) ***	3 (101)	3 (98)

* S indicates that the program was implemented during the summer session.

** AY indicates that the program was implemented during the academic year.

*** Random assignment with findings from Institute for Education Sciences (IES).

There were a total of 10 SRL sections with 253 students and a total of 42 comparison sections with a total of 945 students.

Learning Form is based on a mastery learning approach in which students are given multiple opportunities to use feedback to improve performance. By completing the form, students had an opportunity to demonstrate the degree to which they could constructively use feedback to master the mathematics and EFAP-SRL skills necessary to solve the problem. Students who demonstrated a complete mastery on this reflection form could earn up to 100% of the original credit for a problem. Instructors again used information from the Reflection and Mastery Learning Form to plan lessons that demonstrated the relationship between mathematics content and EFAP-SRL competencies. Some examples of these exercises are presented in the next section.

Classroom discussions and exercises. The quiz/self-reflection process is considered a major classroom priority. Instructors use the collected information to engage in ongoing class discussions that focus on the relationship between effectively learning mathematics content and enhancing their self-regulation skills. One example of such an activity involves having students create individual graphs that illustrate the relationship between their SRL judgments and quiz scores. In another exercise, instructors might ask students to compare the time they spent preparing for the quiz and their quiz grades. These student responses are then listed on the board. The results are often an obvious correlation between the students' preparation time and their quiz scores. Students are then asked to use the feedback from these exercises to design a plan for improving their work.

Performance Measures

Over the course of the four studies we employed up to four different academic outcome measures. The specific combination of measures used in any one study was largely dictated by administrative and financial constraints:

1. Passing the developmental mathematics course: Students who passed the course (i.e., the course examinations) were then eligible to retake the COMPASS examination.
2. Passing the Computer-Adaptive Placement Assessment and Support System (COMPASS): As previously indicated, students were required to retake and pass the COMPASS in order to satisfactorily "test out" of the developmental mathematics course.
3. Enrolling in college-level math course: Students must have successfully completed the developmental mathematics course and passed the relevant sections of the COMPASS then subsequently enrolled in a college-level mathematics course.
4. Passing the college-level mathematics course: For the purposes of this study, student success was measured by assigning either a pass or fail grade at the end of the mathematics course. Grading standards in this first college-level mathematics course are set by the mathematics department and include set weights for class quizzes, final examinations, etc. Students who earned a grade of D or above were considered to have passed the course. A withdrawal or a grade of F was considered a failure to complete the course. A passing grade served as an indication that students were able to successfully transfer their developmental mathematics skills into a subsequent mathematics course.

Results

This section reports the results for the four aforementioned studies (S1, S2, AY1, and AY2). Tables 2 and 3 summarize the data for the two summer studies (S1 and S2), and Tables 4 and 5 summarize the two academic-year studies (AY1 and AY2). Depending on the study, the data reported in these tables contain up to six academic measures: precourse COMPASS scores, developmental mathematics course pass rates, postdevelopmental mathematics course COMPASS pass rates, enrollment status in college-level mathematics courses, pass rates in the college-level mathematics courses for those students who enrolled, and college-level mathematics course pass rates for the original cohort of developmental mathematics students.

We were not able to generate all six academic measures in each study due to administrative and financial constraints. However, Table 6 summarizes the data from the four studies in terms of the three most common academic progress measures: (a) developmental mathematics pass-rates, (b) enrollee pass rates in college-level mathematics, and (c) overall college-level math course pass rates for the original cohort of EFAP-SRL and comparison group students.

Summer Programs Using the EFAP-SRL Model

Summer 2005 (Study S1). Table 2 summarizes the academic progress measures for students enrolled in two EFAP-SRL sections and in six comparison sections of developmental mathematics. More students enrolled in the EFAP-SRL sections passed the course compared to the pass rate of students in the comparison group sections. Both groups of students were monitored during the Fall 2005 semester by tracking their enrollment in credit-bearing mathematics courses. A greater percentage from the original cohort of EFAP-SRL students enrolled in a college-level mathematics course the following semester when compared to the students from the original comparison group sections. Furthermore, a marginally significant percentage of the EFAP-SRL students in the college-level course passed when compared to the more limited number of students from comparison sections that enrolled. Overall, more of the original student cohort who enrolled in EFAP-SRL developmental mathematics sections during the Summer 2005 passed a college-level mathematics course at the end of the Fall 2005 semester.

Summers 2008 and 2009 (Study S2). The data in Table 3 (p. 8) report on the academic progress measures for students enrolled in two summer sections of EFAP-SRL and 16 comparison summer sections of developmental mathematics. At the start of each summer session, there were no significant differences on the prealgebra (arithmetic) section of the COMPASS exam scores for the two groups or on the algebra section of the COMPASS.

Table 2

Descriptive Statistics, Percentages, and Chi Square Tests for Dependent Measures by Groups in Developmental Mathematics for Summer 2005 (Study S1)

	Groups					
	SRL EFAP (*N*=47)		Comparison (*N*=142)			
Academic progress measures	%	(*n*)	%	(*n*)	χ^2	*p*
Passed developmental math	78	(37)	49	(70)	12.69	.002
Enrolled in credit math	77	(36)	39	(56)	18.05	.001
Passed credit math (math enrollees) [1]	83	(29)	63	(35)	3.35	.07
Passed credit math (original cohort) [2]	62	(29) [2]	25	(35)	20.02	.001

[1] Students who enrolled in the college-level mathematics course and passed it.

[2] Those students from the original cohort that passed the college-level math course.

More students in the EFAP-SRL sections passed the developmental mathematics course when compared to the pass rate of students enrolled in the comparison sections. Furthermore, the EFAP-SRL students passed the COMPASS at a higher rate than students enrolled in the comparison group. It should be noted that a few students (less than 10%) from both groups, who failed the COMPASS at the end of the course, retook the test after a short "express" course that took place directly after the regular summer session. Therefore, slightly more EFAP-SRL students enrolled in the college-level mathematics course than originally passed the COMPASS (see Table 3).

In the subsequent semester (i.e., Fall 2008 and Fall 2009) EFAP-SRL students were more likely than comparison group students to enroll in college-level mathematics courses. There was no difference in the pass rate for EFAP-SRL and comparison students in the credit-level mathematics course. More students who enrolled in the EFAP-SRL summer programs during 2008 and 2009 passed a college-level mathematics course by the end of the fall semester.

Academic Year Programs Using the EFAP-SRL Model

Fall 2005 (Study AY1). Table 4 displays the academic program data for EFAP-SRL students enrolled in two sections and students enrolled in eight comparison sections of developmental mathematics. More students enrolled in the EFAP-SRL sections passed the developmental mathematics course than did students enrolled in the comparison sections. Similarly, more EFAP-SRL students than comparison group students enrolled in a college-level mathematics course during the following semester. There were no significant differences in the pass rates in the credit-level math course for the EFAP-SRL students and the more limited number comparison group students. Overall, more EFAP-SRL students who started the EFAP-SRL program in the Fall 2005 semester successfully completed a college-level mathematics course by the end of the next semester (Spring, 2006).

Academic years 2006-2008 (Study AY2). Table 5 (p. 10) reports on a 2-year study funded by the Institute for Education Sciences (IES). It involved students who were randomly assigned to either one of three EFAP-SRL sections or one of three control group sections.

Zimmerman et al. (2011) reported no differences in the presemester COMPASS scores for the two groups. However, the EFAP-SRL group achieved higher mean scores on the last two of three periodic examinations (e.g., M= 70.64 and M = 62.10 for the EFAP-SRL and control group respectively for periodic examination two, F = 4.96, p <.05, and M = 68.06 and M = 54.05 for the EFAP-SRL and control groups respectively for periodic examination three, F = 10.26, p < .05). Similarly, the EFAP-SRL group earned a higher mean score on the uniform departmental final (M = 73.18 and M = 58.03 for the EFAP-SRL and control groups respectively, F = 9.96, p < .05). All of these examinations were independently scored by another member of the mathematics faculty.

As part of this program, the EFAP-SRL staff was trained to make classroom observations using the observation form, see Appendix C. Inter-rater reliability between observers was moderate (.59).

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Table 3

Descriptive Statistics, Percentages, and Chi Square Tests for Academic Progress Measures by Groups in Developmental Mathematics: Summer 2008 and Summer 2009 (Study S2)

	Groups							
	SRL EFAP(43)			Comparison (483)				
Academic progress measures	***n***	***M***	**(%)**	***n***	***M***	**(%)**	χ^2	***p***
Pre-COMPASS – Arithmetic	42	34.45		453	35.86		0.42	n.s.
Pre-COMPASS – Algebra	42	25.23		465	26.52		1.23	n.s.
Passed developmental math	35		(81)	255		(53)	13.03	.001
Pass rates for the COMPASS	26		(61)	213		(44)	4.26	.039
Enrolled in credit math course	28		(65)	183		(38)	8.32	.004
Passed credit math course (math enrollees)[1]	21		(75)	139		(76)	0.06	n.s.
Passed credit math (original cohort)[2]	21		(49)	139		(29)	7.55	.006

Note. The differences in *n* sizes between the pre arithmetic and pre-algebra compared to the total number represented in the comparison are due to the differences among students. For example, one student may have failed portion of the COMPASS whereas another student may have failed both.

[1] Students who enrolled in the college-level mathematics course and passed it.

[2] Those students from the original cohort that passed the college-level math course.

Table 4

Descriptive Statistics, Percentages, and Chi Square Tests for EFAP-SRL and Comparison Groups in Developmental Mathematics: Fall 2005 (Study AY1)

	Groups					
	EFAP-SRL (62)		Comparison (222)			
Academic progress measures	**%**	**(*n*)**	**%**	**(*n*)**	χ^2	***p***
Passed developmental math & COMPASS	60	(37)	23	(51)	28.84	.01
Enrolled in credit math	52	(32)	21	(46)	21.69	.001
Passed credit math (math enrollees)	72	(23) [1]	67	(31)	0.00	n.s.
Passed credit math (original cohort)	37	(23) [2]	14	(31)	15.37	.001

[1] Students who enrolled in the college-level mathematics course and passed it.

[2] Those students from the original cohort that passed the college-level math course.

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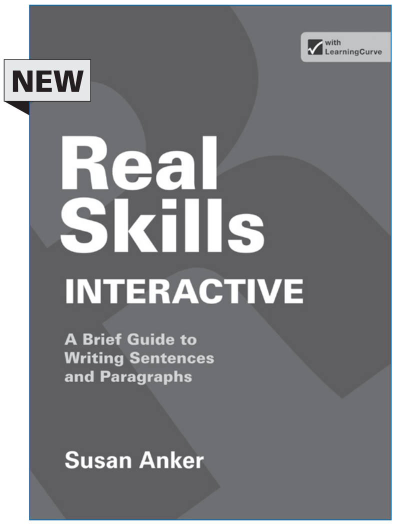

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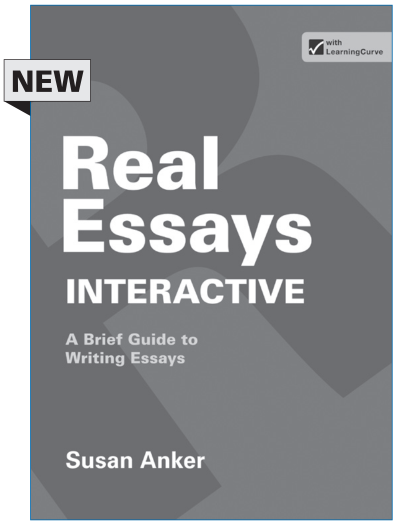

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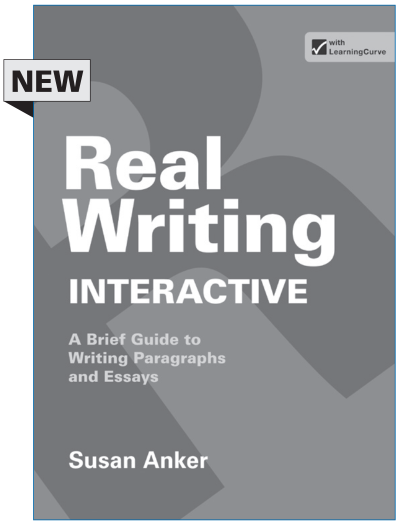

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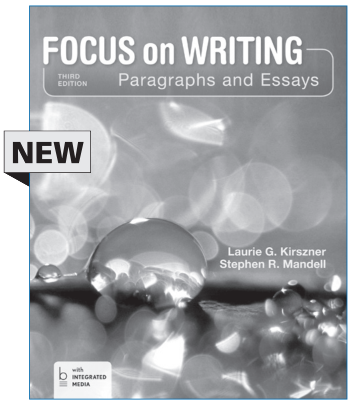

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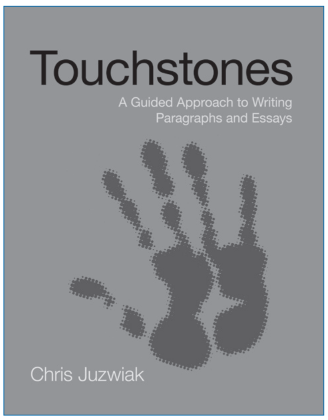

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These observers visited EFAP-SRL and control group classrooms three times each semester and used the classroom observation form to measure the frequency of EFAP-SRL targeted behaviors. EFAP-SRL instructors demonstrated greater use of several targeted EFAP-SRL behaviors ($M = 7.32$, $SD = 2.59$) than did control group instructors ($M = 4.95$, $SD = 2.09$; Zimmerman et al., 2011).

In addition, Table 5 reports a number of benchmark measures for the EFAP-SRL and control group students reflected in the data from this study (Zimmerman et al., 2011). For example, more students in the EFAP-SRL group passed the developmental mathematics course than students in the control group. Those students who passed the course were allowed to retake the COMPASS. Almost twice as many students in the EFAP-SRL group passed the COMPASS than did students in the control group.

A further analysis of the data, which was not included in the original article, indicates that in the subsequent semester more EFAP-SRL students registered for a college-level mathematics course. Of those students who registered for a college-level mathematics course, there was no difference in pass rates for EFAP-SRL and control group students. Overall, more students who initially enrolled in EFAP-SRL sections of developmental mathematics succeeded in passing a college-level mathematics course by the end of the next semester than the original control group students.

Table 6 summarizes student performance for three main academic progress measures that were common to the four studies described separately in Tables 2 through 5. In all four programs, EFAP-SRL students had higher pass rates than comparison groups in the developmental mathematics courses. Similarly, in all four studies, EFAP-SRL students, who *originally* enrolled in developmental mathematics courses, were more likely to have passed a college-level mathematics course by the end of the subsequent semester. In some programs, EFAP-SRL students enrolled in credit-level mathematics courses passed at a higher rate than students from comparison group sections; in other studies, there was no difference in the pass rates for the two groups. However, it should be noted that among the students who passed the EFAP-SRL developmental mathematics course were those who were originally in an academically weaker position than the students from the comparison groups; yet, the EFAP-SRL students, as a group, passed the college-level course at levels at least equivalent to those students in the comparison groups.

Discussion

Over a 3-year period, four programs were implemented to apply the EFAP-SRL model to assist associate degree developmental mathematics students in improving their mathematics achievement. Research on these programs was carried out under a variety of conditions; however, the outcomes have been consistently positive.

EFAP-SRL program students outperformed comparison group students on a variety of academic progress measures, including better pass rates in developmental mathematics courses, and higher pass rates on the COMPASS. In some cases, we were able to demonstrate that, of the original cohort, significantly more EFAP-SRL students successfully completed a college-level mathematics course by the end of the semester following their developmental mathematics course. In other programs, even though the EFAP-SRL groups contained a larger percentage of students who were originally in a weaker academic situation, EFAP-SRL students passed the college-level mathematics course at the same rate as comparison group students. Taken in its totality, these studies support the value of the EFAP-SRL program in assisting associate degree students to improve their performance in both developmental and college-level mathematics.

Study Limitations

As indicated previously, the experience level of mathematics instructor varied considerably. In addition, each study reported includes design limitations due to program development, implementation, and research being funded at varying levels and for different purposes. For example, in two studies of technology (AY 1 and S1), COMPASS prescore data were not collected. We were, therefore,

CONTINUED ON PAGE 12

Table 5

Descriptive Statistics, Percentages, and Chi Square Tests for Dependent Measures by Groups in Developmental Mathematics for Fall and Spring Semesters 2006 – 2008 (Study AY2)

	Groups					
	EFAP-SRL (101)		Comparison (98)			
Academic progress measures	%	(*n*)	%	(*n*)	χ^2	*p*
Passed developmental math	50	(50)	31	(32)	5.83	.05
Passed the COMPASS	47	(47)	27	(26)	8.57	.01
Enrolled in credit math	42	(42)	22	(22)	8.53	.01
Passed college-level math (math enrollees)[1]	60	(25)	59	(13)		n.s.
Passed college-level math (original cohort)[2]	25	(25)	13	(13)	4.25	.05

[1] Students who enrolled in the college-level mathematics course and passed it.

[2] Those students from the original cohort that passed the college-level math course.

Table 6

Descriptive Statistics, Percentages, and Chi Square Tests for Academic Progress by Groups in Developmental Mathematics for Studies 1 -4

	Academic program measures					
	Percent passed dev. math		Percent of enrollees passing credit math		Percent of original cohort passing credit math	
Program	Exp.	Comp.	Exp.	Comp.	Exp.	Comp.
Summer 2005 (S1)	78% *	49%	83%	63%	62% **	25%
Summer 2008-2009 (S2)	81% **	53%	75%	76%	49% **	29%
Study 3: Fall 2005 (AY1)	60% **	23%	72%	67%	37% **	14%
Study 4: 2006 -2008 (AY2)	50%*	31%	60%	59%	25%*	13%

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

CONTINUED FROM PAGE 10
forced to infer that there were no initial differences between the EFAP-SRL and comparison student groups; this inference was based on the fact that no pre-COMPASS score differences were found in another study (S2) using the same procedures for assigning students to conditions. Similarly, in another study that was supported by the Institute for Educational Sciences (Zimmerman et al., 2011), we were able to initiate a randomized controlled study that included more rigorous procedures including collection of pre-COMPASS scores (where no differences were found), assessment of program fidelity of implementation, and follow-up of EFAP-SRL and comparison students in subsequent mathematics courses.

Implications for Research and Practice with the EFAP-SRL Program

Since the current studies only investigated the impact of the program as a whole on students in developmental mathematics, future research is needed to investigate causal mechanisms within the different EFAP-SRL program components and its application across different disciplines. This evaluation might be accomplished by studying the impact of increasing the frequency of quizzes, as well as the role of various content and metacognitive feedback opportunities. This research would investigate the program under five conditions: (a) students who receive a "business as usual" condition; (b) students who receive increased quizzes only; (c) students who take more quizzes together with content-only formative assessment (i.e., the self-reflection form only deals with the mathematics content); (d) students who take more quizzes and receive metacognitive-only self-reflection forms; and, finally, (e) students who receive more quizzes and both content and metacognitive formative assessment (i.e., a self-reflection form or exercise).

On occasion, new instructors expressed concern over the extra work that they and their students must fit into an already tight curriculum: the extra quizzes, reflection and revision forms, and the accompanying classroom exercises. Instructors also reported feeling out of their element; they told us they are mathematicians, not educational psychologists. Therefore, they did not feel comfortable engaging students in what they believed to be psychological rather than mathematical exercises. We believe that some of these instructor concerns can be addressed by using technology to make the assessment and quiz portion of the program more efficient. For example, Hudesman et al. (2011) reported on the use of a tablet PC to automate the administration and scoring of the EFAP-SRL quizzes. This technology allowed students and instructors to create individual and class-wide summary data tables and graphs that illustrated the relationship between mathematics content and SRL skills. Students and the instructor reported that using the tablet PC made the quiz-taking and feedback process more engaging. There is an increasing interest in the application of technology to increase the efficiency of the SRL model in a variety of academic disciplines (e.g., Kitsantas, Dabbagh, Huie, & Dass, 2013).

Another possible direction for improving the delivery of the EFP-SRL program would be to develop collaborations. Classroom instructors could deliver the mathematics portion of the course and specially trained tutors or counselors could teach the metacognitive portion of the course.

Conclusion

The need to improve academic outcomes for students enrolled in developmental skills courses has been the subject of much discussion and research. Most attempts to deal with this issue have been focused on the development and delivery of academic content material (Black & Wiliam, 1998a, 1998b, 2009). The research we have reported on, when taken together with an ever growing body of other work, has demonstrated the importance of integrating formative assessment and metacognition with academic content instruction so that students can optimize their learning. In this paper we have presented some examples of how this approach can be implemented as part of an EFAP-SRL Program. Results of implementation to date reflect the program's positive impact on student success and retention, making it an important tool for instructors to consider integrating into their instructional tool box.

The tablet PC made the quiz-taking and feedback process more engaging.

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Appendix A: A Sample EFAP Math Quiz

Name: ______________________ Date: __________ Quiz #: ________

Predicted Score: __________ Preparation Time: __________ mins.

Before solving each problem, how confident are you that you can solve it correctly?	**REMEMBER! Show all your work. Simplify all your answers.**	**After** you have solved each problem, how confident are you that you solved it correctly?
0% 25% 50% 75% 100%	1. Factor completely: $10x^4y + 4xy^2 - 2y =$	0% 25% 50% 75% 100%
0% 25% 50% 75% 100%	2. Divide: $8a^3b^2 - 12a^2bc + 4ab$	0% 25% 50% 75% 100%
0% 25% 50% 75% 100%	3. Express answer in scientific notation: a) 6700000 b) 0.000015	0% 25% 50% 75% 100%
0% 25% 50% 75% 100%	4. Compute and express in scientific notation: $(3.6 \times 10^{-4})(6 \times 10^{6})/1.2 \times 10^{-3}$	0% 25% 50% 75% 100%
0% 25% 50% 75% 100%	5. Multiply: $(5x - 3)^2$	0% 25% 50% 75% 100%

Appendix B: Sample EFAP Revision Form

SRL Math Revision Sheet, Quiz #___ Item #___
Student: ________________ **Date:** _______
Instructor: ________________

Now that you have received your corrected quiz, you have the opportunity to improve your score. Complete all sections thoroughly and thoughtfully. Use a separate revision sheet for each new problem.

PLAN IT 8pts

1. a. How much time did you spend studying for this topic area? ______

b. How many practice problems did you do in this topic area ______________ in preparation for this quiz?

(circle one) 0 – 5 / 5 – 10 / 10+

c. What did you do to prepare for this quiz? (use study strategy list to answer this question)

2. After you solved this problem, was your confidence rating too high (i.e. 4 or 5)? yes no

3. Explain what strategies or processes went wrong on the quiz problem.

PRACTICE IT 8pts

4. Now re-do the original quiz problem and write the strategy you are using on the right.

Definitely not confident Not confident Undecided Confident Very confident

5. How confident are you now that you can correctly solve this similar item?

1 2 3 4 5

6. Now use the strategy to solve the alternative problem. 4pts

7. How confident are you now that you can correctly solve a similar problem on a quiz or test in the future? 4pts

1 2 3 4 5

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