BUILDING STUDY SKILLS IN A COLLEGE MATHEMATICS CLASSROOM

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Introduction

Remedial mathematics courses continue to be a large and increasing part of the instructional program at most postsecondary institutions (Fulton, 1996; Grubb & Kalman, 1994). The problematic nature of these courses is leading some universities to seek radical solutions. For example, the Board of Trustees of the City University of New York recently announced its controversial plan to phase out most remedial education beginning in January 2000 (Hebel, 1999). The California State University System adopted an equally controversial policy allowing students only one year to complete all remedial coursework (CSU Office of Public Affairs, 1999). Florida, Massachusetts, Georgia, Texas, and Virginia are considering or have already implemented similar policies that will impact the number of remedial courses taught at community colleges (Shaw, 1997).

Yet present trends indicate that the need for remedial mathematics at the postsecondary level is likely to continue. Young (1993) reported that more than half of all mathematics registrations were in courses below the level of calculus. Moreover, the need for remedial mathematics was recently underscored by the results of the Third International Mathematics and Science Study (TIMSS), which compared the mathematics performance of 12th graders in different countries and found U.S. students near the bottom of the scale (12th Grade Results of TIMSS, 1998).

The large and increasing number of mathematics students who require remediation and the failure of many teaching programs to help these students presents the mathematics community with an

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important challenge (Adelman, 1995; Young, 1993). The study presented in this paper tested a program of teaching lower-level (remedial) mathematics with the ultimate goal of increased mathematics performance, work, study, and concentration skills. We employed techniques derived from developmental psychology intertwined with educational theories on cognitive student mediation, teaching strategies, and good practices in undergraduate education (Chickering & Gamson, 1987; McKeachie, Pintrich, Lin, & Smith, 1986).

Review of the Literature

Developmental Psychology

Unsuccessful college students do not necessarily lack intelligence or a desire to succeed. Rather, they are constrained by learned or acquired behavior patterns that inhibit advanced learning (Fad & Ryser, 1993; Hodges, 1981; Miglietti & Strange, 1998; Robinson, 1994). Examples of behaviors and learned conditions detrimental to learning include the following:

- short attention spans, the inability to concentrate on a task for more than a few minutes (Horn & Packard, 1985; Lee & Meyer, 1994; Soraci et al., 1986);
- little or no attention to assigned homework (Keith, 1982; Robinson, 1994; Vratanina, 1988);
- short time horizons, deadlines more than a few days away are rarely acted upon (Beswick, Rothblum, & Mann, 1988; Solomon & Rothblum, 1984);
- failure to learn from mistakes, in particular the inability to use mistakes on exams as guides for further study (Hodges, 1981);
- passivity, the hope to pass a course without being noticed and the failure to ask for help when needed (Hodges, 1981; Lee & Meyer, 1994);
- poor attendance patterns (de Jung & Duckworth, 1985, 1986);
- low levels of self-esteem (Calsyn & Kenny, 1977; Carr, Borkowski, & Maxwell, 1991; Garfield, 1993).

Of course, the aforementioned conditions apply to the general educational environment, not just mathematics. Therefore, any successful attempt to change student behaviors in a way that promotes success in mathematics has the potential of promoting success in other subjects as well.

Intervention

According to the cognitive and instructional psychology literature, appropriate process-oriented instructional practices can mediate and counteract the aforementioned behaviors and learned conditions (Murray, 1991; Pintrich, Cross, Kozma, & McKeachie, 1986). Thus, the teaching of learning strategies (i.e., how to learn) may be as important as the teaching of academic content (i.e., what to learn). The teaching of learning strategies provides assistance to learners as they process information and structure it in memory (Farnham-Diggory, 1977). According to Weinstein and Mayer, "Good teaching teaches students how to learn, how to remember, how to think, and how to motivate themselves" (1986, p. 315). More specifically, Weinstein and Mayer identified categories of learning strategies that affect the encoding process and subsequent learning outcomes and performance. The categories are provided in Table 1.

The teaching of learning strategies appeared to be quite effective in a study reported by Weinstein and Underwood (1985). The study used elaboration and self-monitoring strategies to increase reading comprehension, reduce anxiety, and improve grades in subsequent coursework. The work of Treisman (1992) provided

Table 1. Learning Strategies and Outcomes

Learning Strategy	Teaching students to:
Rehearsal	Repeat and/or restate information
Elaboration	Form mental images through paraphrasing summarizing, and describing
	Relate new information to that already learned
Organizational	Sort and/or group information
	Create informational hierarchies
Comprehension monitoring	Check for self-learning
Affective strategies	Be attentive, alert, relaxed, free of test anxiety, etc.

another excellent example of the success of positive learning strategies. Treisman taught African American and Hispanic college calculus students how to study cooperatively, encouraged them to apportion appropriate study time, and taught them how to check for comprehension. The result of this classic experiment was that the African American and Hispanic students outperformed their White and Asian counterparts.

Others have proposed similar frameworks for counteracting the learned or acquired behavior patterns that inhibit advanced learning. For example, Rosenshine specified the following six active teaching and learning strategies to teach students how to learn and to be successful students:

1. Review and provide feedback on daily work with re-teaching sessions whenever required.
2. Present new material in small but rapid steps.
3. Closely monitor student progress.
4. Provide consistent and prompt feedback.
5. Eliminate failure through independent student practice until a high rate of success occurs (90–100%).
6. Provide consistent and regular (weekly or monthly) cumulative reviews. (1983; Rosenshine & Stevens, 1986)

The remainder of our literature review will focus on how the aforementioned strategies and frameworks can be appropriately applied to specific instructional methods.

The Role of Quizzes and Tests

In addition to providing a means for consistent monitoring of comprehension, frequent tests and quizzes teach students to apportion regular study times and promote positive organizational strategies. While infrequent tests encourage cramming, more frequent monitoring encourages positive study habits (Dempster, 1992; Geist & Soehren, 1997; Mawhinney, Bostow, Laws, Blumenfeld, & Hopkins, 1971). Using frequent tests to section the presentation of knowledge into smaller manageable units is consistent with information-processing theories, which state that learners have limits to the amount and intensity of information that can effectively be encoded in the short run (Beck, 1978; Miller, 1956). In addition, frequent testing can serve as an affective strategy to counteract test anxiety. Dempster (1992) reported a significant reduction in test anxiety with the consistent use of short quizzes rather than long tests. Others have reported that students prefer frequent quizzes over fewer tests that carry exorbitant weights in the determination of final grades (Bangert-Drowns, Kulik, & Kulik, 1991). Even the arousal produced by tests may play an important role in the learning process. According to Kleinsmith and Kaplan (1963, 1964), work in a low arousal state produces better short-term recall while work in a high arousal state, such as in a timed test, may produce better long-term memory. The biological mechanism for enhanced long-term memory associated with emotional arousal is fully discussed in Cahill, Prins, Weber, and McGaugh (1994) and Cahill, Babinski, Markowitsch, and McGaugh (1995). These findings have important classroom implications. When new material requiring more immediate recall is presented, a low arousal state is preferable. In the second stage, however, when the organized material should be consolidated in long-term memory, a high arousal state is more appropriate.

Of course, the contents of quizzes and tests is also an important factor in learning outcomes. Both Dempster (1992) and Nungester and Duchastel (1982) reported higher levels of learning when cumulative testing was used. Cumulative testing may motivate students to review earlier topics and concepts at a time when they have the hindsight of later understanding. The hierarchical nature of mathematics (i.e., the understanding of present topics depends on the understanding of previous topics) may make cumulative testing particularly appropriate.

Equally important is the relative timing of quizzes and tests. Testing material closely after it is presented encourages good performance, self-efficacy, and later success (Dempster, 1992; Spitzer, 1939).

Grading Curves

The use of grading curves is an extremely common practice in U.S. postsecondary classrooms. Although many believe the practice provides fairness, others feel that grading on a curve gives students a wrong message (Bishop, 1995). Grading on a curve places students in competition with each other, rather than with standards of excellence, and may discourage cooperation (Gold, 1966; Halley et al., 1973). Also, the use of curves in a remedial classroom may allow students to be promoted from one level to another without mastery of the material, since the curve in these classes is determined by the performance of other unsuccessful students. Grading on a curve can provide confusing messages; for example, when a grade of B "on the curve" is assigned to a score of 62, the student may be led to believe that 62% is good enough.

Cooperative Learning

Cooperative learning promotes student motivation, builds group skills, fosters social and academic interaction, and promotes effective individual learning (Davidson, 1990; Johnson & Johnson, 1989; Larson, Dansereau, O'Donnell, Hythecker, Lambiotte, & Rocklin, 1984; Sharan, 1990; Slavin, 1983, 1990, 1995; Yager, Johnson, & Johnson, 1985). In a published interview (Garland, 1993), Treisman stated that, in his study, the use of cooperative groups was a powerful remedy against one of the two features that separated students with mathematics difficulties from those who succeeded—isolation. Moreover, students who participate in cooperative learning are also more likely to attend class regularly (Slavin, 1990, 1995). In the specific environment of the college mathematics classroom, several researchers have reported positive academic and social outcomes as a result of using cooperative groups (Hofer, 1994; Treisman, 1992).

Homework

Used appropriately, homework can be a learning reinforcement while providing rehearsal in the subject area (Foyle & Lyman, 1989). In addition, homework can monitor comprehension and indicate areas needing further elaboration and practice. Studies of students of all levels have indicated that homework increases achievement (Foyle & Bailey, 1986; Keith, 1982; Paschal, Weinstein, & Walberg, 1984).

Although the majority of postsecondary teachers assign homework, the quantity and quality of teacher attention to homework varies widely. Surprisingly, the literature is silent regarding this aspect of teacher work. However, we authors (all college teachers) conservatively estimate that grading homework appropriately would take approximately 15 minutes per student per week. A typical community college teacher instructing four classes would have approximately 140 students. Therefore, if all students hand in homework, and the teacher conscientiously grades it, he/she would spend a monumental 35 hours per week on this task. Since college teachers cannot do that, many check-mark papers and give credit for the work without judging the output or giving feedback. Thus, students are not given the opportunity to learn from their mistakes. They are also given the wrong message that the mere appearance of work counts as much as work well done.

Method

Study Site and Sample

The study site was a large community college located in a blue-collar area in a major Midwestern metropolitan city. The college enrolled 4,679 students in credit programs in the fall of 1995 (Office of Planning and Research, 1995). At the time of the study, approximately 62% of all mathematics enrollments were remedial and 91% were below the level of calculus.

The study sample consisted of 332 students enrolled from the spring of 1993 to the spring of 1995. The sociological characteristics of the sample and the study site are presented in Table 2.

We assigned intact classes as treatment or control because it was not possible to assign students randomly. Rosenshine and Stevens (1986) acknowledged the difficulty (or, in most cases, impossibility) of true random assignment of students into experimental and control groups in their chapter in the *Handbook of Research on Teaching.* They label studies taking "place in regular classroom [where] one group of teachers received training in specific instructional procedures and one group continued their regular teaching" as experimental (p. 376). However, since random

Table 2. Sociological Characteristics of Sample as Compared to the Entire College

	Ethnicity by Percent			Gender by Percent		Age & Employment		Feeder Institutions			
	African American	Hispanic	Non-Minority[a]	Male	Female	Average Age	% Employed[b]	City		Not City	% GED
								% Public	% Private		
College	30	32	36	39	61	26	59	51	19	18	9
Sample	30	33	37	42	58	23	57	56	19	19	6

[a]Non-minority at this college includes 33% White and 3% Asians/Pacific Islanders.
[b]Includes both full- and part-time employment. The students in the study worked an average of 26 hours per week.

assignment was not possible and intact classes were designated as either control or treatment, our design is more appropriately termed quasi-experimental with a non-equivalent control group (Caporaso, 1973; Mason & Bramble, 1978). Students signed up for classes unaware that certain sections were to be included as treatment and others as control. In total, there were 12 treatment classes and 4 control classes. Control classes consisted of 2 sections of elementary algebra and 2 sections of college algebra taught during the fall 1993 semester. The treatment sections consisted of one section of elementary algebra and one section of college algebra taught each semester from the spring of 1993 to the spring of 1995, except during the fall of 1993, when 2 sections of each algebra type were designated as treatment. On the first day of classes, students in the college received a syllabus and a list of course requirements written by each instructor. The course requirement in the treatment classes reflected the project policies; however, no mention was made of a project or an experiment. No unusual level of section switching occurred after these announcements.

Conceptual Framework

The conceptual framework for this study was based on the teaching strategy and good practice literature exemplified by Weinstein and Mayer (1986), Rosenshine (1983; Rosenshine & Stevens, 1986), and Chickering and Gamson (1987). Table 3 provides a summary of specific components of instruction as applied in this quasi-experimental study.

Materials and Classroom Management

Both treatment and control classes met twice a week for 100 minutes per session. The control classes utilized the exact same materials used in past semesters (e.g., textbooks, worksheets, and tests). In addition to the standard textbooks, the treatment classes utilized additional instructor-prepared problem sheets, daily quizzes, and frequent teacher-prepared tests—all designed to provide comprehension monitoring, review, and immediate feedback (Baiocco & DeWaters, 1998; Chickering & Gamson, 1987; Rosenshine, 1983; Weinstein & Mayer 1986). To encourage high expectations (Chickering & Gamson, 1987)

Table 3. Conceptual Framework

Educational Component	Control Classes	Treatment Classes	Observed Outcomes in Treatment Classes
Testing	Traditional (i.e., midterm and final exams) Partial credits given at the teacher's discretion	Daily, time-pressured, cumulative, homework based. Partial credits not given.	Increased attention span, student awareness of progress
Homework	Logged in, no feedback provided	Feedback provided for those flagged as needing assistance	Improved performance on quizzes and complete homework assignments
Expectations	Typical community college students	Students will meet frequent deadlines	Adherence to deadlines
Feedback	Typically infrequent (usually only on midterm and final exams)	Immediate feedback from all quizzes	Students learn from mistakes
Teaching methodology	Lecture	Combination of lecture, cooperative grouping, and peer tutoring	Active classroom participation
Attendance policy	None articulated	Administrative drops for poor attendance	Good attendance patterns
Task delineation	Relaxed	Clearly defined	Positive levels of self-esteem from achieving mini-goals
Code of behavior	Not clearly defined	Consistent and clear	Respect for teachers' statements
Grading	On curve	On absolute scale	Clear and consistent messages

and promote intense concentration, students in the treatment classes were not permitted to use calculators. The College Board Descriptive Tests were used as pre- and post-test instruments for both the treatment classes and the control classes.

Treatment classes began with a short, student-directed review and discussion of student problems. This was followed by a timed multiple-choice quiz that tested cumulative knowledge and the current homework assignment. Students arriving late for class were not granted additional time for the quiz. The time allotted to each quiz was carefully calculated to promote work with full concentration and was strictly enforced. Absent students received a score of zero. The answer sheets were collected, but the students were allowed to keep the question sheet and were encouraged to use it for further review at home.

Item analysis of each quiz permitted the identification of weaknesses and concepts needing further clarification and re-teaching. Items on which the class scored poorly were reviewed in class and re-examined. Special attention was paid to the standard deviation of scores. A large standard deviation may indicate splitting: the top students performing well while the weak students struggle. This situation creates a difficult teaching dilemma. If the teacher continues, the weak students will be lost. However, re-teaching may bore the strong students. Whenever the standard deviation exceeded 25%, cooperative learning techniques were employed. The use of statistical measures to direct instruction is not new; Rosenshine and Stevens suggested that "guided practice should continue until a success rate of 80% is achieved" (1986, p. 379). However, using standard deviation statistics to diagnose "class splitting" and responding with cooperative learning techniques seems to be new. After the cooperative learning took place, the concepts were included in a quiz, so that mastery was again tested. In addition to quizzes, students were given several longer tests and a final examination. In all project classes and on all tests, students were graded on an absolute scale.[1] In total, the treatment method conveyed high expectations, emphasized time on task, and provided comprehension monitoring.

Cooperative Learning Groups

As stated earlier, when the results of quizzes in the treatment classes indicated great variation in mastery, cooperative group techniques were employed and used as a re-teaching strategy. Groups were composed of four students, one from each quartile of the class. Each group was given a problem sheet written to address the weaknesses indicated on the quiz. Although each student was given a copy of the problems, students were encouraged to discuss their work within the group. To reward students' cooperative efforts (and to provide individual practice), a quiz based on the problem sheet was always administered after time spent in cooperative learning groups. When the standard deviation for these quizzes dropped to about 18%, traditional teaching was resumed.

Assessment

To determine the efficacy of the teaching program, we assessed the project in three ways: (a) the percent of students who completed the course (retention), (b) students' performance in mathematics, and (c) the students' ability to work with full concentration. Retention was measured by comparing the official enrollment figures for the second and the last week of each semester for each class. The rates of retention of the 12 treatment classes were compared via an independent *t* test to the rest (40 sections) of the college's weekday elementary and college algebra courses offered during the period of the study.

Since the institution where the study was based does not mandate common final exams,[2] we were not able to measure directly the mathematics performance of the treatment students compared with a control group of students. As an alternative, we administered the final exam given to one of the treatment classes (college algebra) to a class of college seniors enrolled in a mathematics education class (i.e., students training to be high-school mathematics teachers) at a large, Research I, public university, for comparison.

Finally, the ability to work with full concentration was assessed through performance on arithmetic and reading comprehension tests. We administered to each student a 20-minute arithmetic and 45-minute reading comprehension pre-test at the beginning of the semester and a similar post-test at the end of the semester.[3] In all cases, the arithmetic test was administered first, followed by a 10-minute rest period prior to the administration of the reading test. For both the arithmetic and the reading tests, 6 of the treatment groups used form K as a pre-test and form L as post-test while the reverse (L as pre-test and K as post-test) was practiced with the remaining 6 treatment groups. Results from both arithmetic and reading were expressed as percentile standings as compared with college and university students nationally. The statistical significance of the gains was measured by dependent *t* tests.

Homework

Because of the impracticality of grading and providing feedback on every homework assignment for every student, we thoroughly reviewed only the homework of students who failed to show improvement on successive quizzes. Homework was therefore not routinely collected or logged in.

Results

Retention

From the second week to the end of the semester, the treatment classes lost an average of 6.7 students while the control classes lost an average of 8.3 students. The difference in retention (proportion of students retained) was statistically significant ($z = 2.1$, $p < .05$). The standard deviation of retention was also much lower for the treatment classes. If the sample is divided into elementary and college algebra, the standard deviations for the control groups were 12% and 13% respectively whereas the standard deviations for the treatment classes were both 4%. This difference indicates that the variation in retention rates may be independent of the class taught, but dependent on whether the classes belonged to the treatment group or the control group. Table 4 provides specific details on the retention component of the project.

Table 4. Retention Results

		2nd Week of Class	End of Semester	Change	Retention Percentage
Project	*M*	36.0	29.33	-6.67	81
(*N* = 12 classes)	*SD*	3.30	3.28	1.78	4
Control	*M*	35.38	27.13	-8.25	77
(*N* = 40 classes)	*SD*	4.47	6.82	4.98	14

NOTE. The standard deviation figures in the "Change" column refer to the standard deviation of the changes.

Mathematics Performance

The treatment group scores on the final exam (M = 70; SD = 22) was not statistically different (t = 0.29, p > .20) from that of the control group of students (M = 68; SD = 14) from the Research I institution. Unlike the treatment group of community college students enrolled in lower division mathematics, the control group for this comparison was a class of college seniors just one semester away from student-teaching assignments in high-school mathematics.

Ability to Work with Full Concentration

Arithmetic cut time results

The arithmetic skills tests used to assess concentration skills covered material that was at a lower level than the material taught in any of the classes (treatment or control). For that reason, students were given only 20 minutes to complete the pre- and post-tests despite the College Board's recommendation of 30 minutes. Table 5 provides the results for both the treatment classes and the control classes. Although the treatment and control group pre-tests were statistically equal (percentile points of 24.17 treatment and 25.49 control), the treatment group post-test gain was over 21 percentile points, which is highly significant. The gain in the control classes, however, was not significant. To eliminate possible confounding effects of different student populations in different semesters, we also provide the results of students in treatment classes that were enrolled during the same semester as the control group. The results indicate improvement of performance in the single-semester subsample as well as for the full treatment group.

Reading comprehension test

Table 5 also displays the reading comprehension gains for all treatment classes. Since the percentile scores show the relative position of the students among their peers in the United States, the increase of 12.3 percentile points in the reading scores means that in 15 weeks the students leaped over one-eighth of their peers.

Table 5. Percentile Scores of the College Board Tests for Treatment and Control Classes

	Arithmetic (Cut Time)				**Reading Comprehension (Full Time)**			
	Pre-test	Post-test	Change	*t* Value	Pre-test	Post-test	Change	*t* Value
Total Treatment Group (N = 332[a])	* 24.17	45.87	21.71	19.89^{***}	45.36	57.67	12.32	15.70^{**}
SD	(25.38)	(29.89)	(19.80)	(4.51^{***})	(29.07)	(27.05)	(14.34)	(2.66^{**})
Treatment Group subsample Fall 1993 (N = 101[b])	23.68	43.51	19.83	9.95^{***}	45.03	58.01	12.98	11.88^{***}
SD	(23.89)	(29.24)	(20.02)	(2.96^{**})	(29.51)	(26.86)	(10.98)	(2.55^{ns})
Control Fall 1993 (N = 45[c])	25.49	24.49	-1.0	$-.47^{ns}$	44.80	32.62	-12.18	-4.44^{***}
SD	(24.46)	(24.77)	(14.30)	(0.15^{ns})	(27.18)	(23.94)	(18.40)	(1.26^{ns})

Note. The standard deviation figures in the "Change" columns refer to the standard deviation of the changes.

[a]pre-test/post-test correlations math r = 0.75; reading r = 0.87
[b]pre-test/post-test correlations math r = 0.73; reading r = 0.93
[c]pre-test/post-test correlations math r = 0.83; reading r = 0.75
[ns] = not significant (p > .05 (for treatment subsample p > .01))
** p < .01
*** p < .001

Table 6. Percentile Scores of the College Board Tests for Treatment Classes reported by Quartile

	Arithmetic (Cut Time)				**Reading Comprehension (Full Time)**			
	Pre-test	Post-test	Change	*t* Value	Pre-test	Post-test	Change	*t* Value
Quarter 1								
(*N* = 83)	62.8	78.9	16.1	9.52***	84.4	88.82	4.42	6.95***
SD	(17.9)	(17.5)	(15.4)		(8.19)	(7.65)	(5.79)	
Quarter 2								
(*N* = 83)	23.3	51.3	28.0	11.98***	56.98	69.07	12.10	9.04***
SD	(6.8)	(21.7)	(21.3)		(9.03)	(14.28)	(12.20)	
Quarter 3								
(*N* = 83)	8.9	32.5	23.6	10.14***	30.24	43.19	12.95	7.79***
SD	(3.5)	(22.4)	(21.2)		(7.02)	(16.36)	(15.15)	
Quarter 4								
(*N* = 83)	1.9	20.8	18.9	9.02***	9.81	29.61	19.81	10.46***
SD	(1.1)	(19.4)	(19.1)		(4.94)	(17.34)	(17.25)	

Note. The standard deviation figures in the "Change" columns refer to the standard deviation of the changes.

*** $p < .001$

Note that the pre-test standings (percentile points of 45.4 treatment and 44.8 control) are not statistically different, showing that the treatment and control groups were well matched. The decline of over 12 percentile points in the average performance of students in the control classes is also statistically significant.

Effects on students with different ability levels
We wanted to find out whether the effect was extended to both strong students and weak students. We therefore divided the students into four groups according to their pre-test scores. Table 6 reports the results of each quartile in both arithmetic and reading comprehension. There were significant percentile improvements by students at each level of competence.

Conclusions

Retention

The higher retention rates in the treatment classes were attained despite tests at each class meeting, grading on an absolute scale, and no partial credits given. Furthermore, there was a relatively large number of students who clearly understood that they were not doing passing work and still decided to remain in the class. This is particularly interesting since the college has liberal drop policies; students are allowed to drop classes without penalties until two weeks prior to the end of the semester.

Mathematics Performance

The nonsignificance of the comparison between the treatment group students and the control group students (from the Research I university) is very important to this study. It could easily be argued that control group students were much better prepared than treatment group students. The controls were seniors only one semester away from student teaching in high-school mathematics classes. The control group students had taken many more courses in mathematics than the students in the project class.[4] Furthermore, the control group was a self-selected group of individuals who chose to be mathematics teachers and devote their life's work to mathematics. The comparison with this self-selected, motivated, and educated group leads to the conclusion that the treatment classes had mastered the material.

Ability to Work with Full Concentration

College Board pre-test/post-test results

Participation in the project classes produced large increases in the students' achievements in arithmetic and reading comprehension tests. We believe that there was a common cause for the improvements in both exams, since the correlation between the students' improvements in the two topics, 24%, given a sample size of 332, enables us to state that the probability that the improvements are uncorrelated is less than .001 (t = 4.49).

The overall improvement of treatment students was especially evident after the improvement for each of the four quartiles was compared. Interestingly, students in the lowest group had higher reading comprehension gains than students in the third group. Students in the third group had higher gains than students in the second group.

Another way of measuring the effect of a program on the spread of the students is the change in the standard deviation of the students' scores. As seen in Table 5, the standard deviation in the arithmetic test for the project classes increased by 18% as the mean jumped by close to 90%. The increase in the standard deviation was largely due to the unnatural compression of the scores in the bottom 25% of the students in the cut-time exam. These students

Table 7. Percentile Scores in Arithmetic (Cut-Time) Tests for the Top 75% (N = 249)

	Pre-test	Post-test	Change	t Value
M	31.67	54.77	23.10	17.99***
SD	25.45	27.70	20.26	1.89^{ns}

Note. The standard deviation figures in the "Change" column refer to the standard deviation of the changes. Pre-test/post-test correlation r = 0.71.
^{ns} p > .05
*** p < .001

who scored in the extremely narrow 1–4 percentile range in the pre-test spread out considerably in the post-test. To verify our point, we analyzed the scores for the top 75%, as shown in Table 7. The students in the top 75% achieved very large gains, but without a significant increase in their scores' standard deviation.[5] We conclude that the spreading out of the bottom 25% of students in the post-test is the main factor in changing the overall standard deviation of the scores.

Limitations and Implications

The present study has several limitations. First, as indicated earlier, a true experimental design was not possible. Second, since the class requirement statement given to the students in the treatment classes asserted high standards and strict policies, the students may have adjusted their attitudes. Such an adjustment may account for some of their success, similar to a Hawthorne effect. Finally, one community college instructor in one institution obtained the reported results.

The study also leaves open some important questions: Will a second semester of treatment show additional improvement? How many semesters of treatment are needed for the newly acquired skills to take hold and persist beyond the treatment period?

The most immediate task is to repeat the experiment on a larger scale. Longitudinal studies with the treatment groups are needed to answer the question of persistence of results beyond the treatment period.

Conclusions and Policy Implications

The magnitude of our success was gratifying. Other programs have also been successful. For example, through their Academic Excellence Workshops, California State Polytechnic University has reported that workshop students scored above their classmates in calculus (Garland, 1993; Hiemenz & Hudspeth, 1993). Another mathematics workshop program, the Emerging Scholars Program at the University of Wisconsin, has reported that their minority calculus students outperformed their traditional counterparts (Millar, 1996). However, since these programs functioned as workshops external (and supplementary) to the college classroom, their results are outcomes of devoting additional resources to self-selected groups of students. The present study provides evidence that dramatic changes in college mathematics outcomes are possible within the regular classroom environment without the large investment of additional resources.

The results of this study further suggest that adjustments in teaching methodology in mathematics can result in gains, not only in mathematics, but also in other areas of general education. Important skills such as working with increased concentration may improve from innovative teaching of subject content. Furthermore, teaching methodologies can have a significant effect on the classroom retention rate. Cooperative groupings appear to work. Although not a panacea for all classroom woes, the results of this study appear to support numerous other research reports stating that the proper usage of cooperative groupings is an appropriate method for dealing with mixed ability classrooms. Finally, perhaps it is time to view testing in a more positive light. It may be that, contrary to current beliefs, emotional stress and upheaval are not the only outcomes of testing. Testing should be viewed as a form of teacher-student dialogue and, as such, a formidable educational tool.

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1. 90–100% for an A, 80–89% for a B, 70–79% for a C, 60–69% for a D, and 0–59% for an F. No partial credit was given; only correct final answers earned credit.

2. Each instructor chooses his/her own textbook and, within broad guidelines, has discretionary choice of topics covered in the final exam.

3. Arithmetic pre-test and post-test were forms M-3KDT and M-3LDT (forms K and L) respectively of the College Board's Descriptive Tests of Mathematics Skills in Arithmetic Skills (Assessing Basic Academic Competencies Identified in Academic Preparation for College). Each test contained 35 multiple-choice questions. The reading comprehension pre-test and post-test were also M-3KDT and M-3LDT (forms K and L) of the College Board's Descriptive Tests of Language Skills in Reading Comprehension (Assessing Basic Academic Competencies Identified in Academic Preparation for College). Each test contained 45 multiple-choice questions.

4. Each student in the control group had taken one semester of trigonometry, three semesters of calculus, and most of the following subjects: one semester of analysis, one semester of abstract algebra, one semester of linear algebra, Euclidean geometry, and projective geometry.

5. An increase in the standard deviation would indicate that a wider variation in ability level was evident at post-test than was evident at pre-test. When the standard deviation significantly increases, it may indicate that the treatment increased the scores of only a portion of the sample.