Building Study Skills In A College Mathematics Classroom

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 plan to phase out most remedial education beginning in January 2000 (Hebel, 1999). Similarly, 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 also are considering or have already implemented similar policies that will impact the number of remedial courses taught at community colleges (Shaw, 1997). Young (1993) reported that more than half of all mathematics registrations were in courses below the level of calculus. Moreover, present trends indicate that the need for remedial mathematics at the postsecondary level is likely to continue. This need 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 Third International Math and Science Study, 1998). The large and increasing number of mathematics students who require remediation and failure of many teaching programs to help these students presents the mathematics community with an important challenge (Adelman, 1995; Young, 1993). The present study 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 the educational theories on cognitive student mediation, teaching strategies, and good practices in undergraduate education (Chickering & Gamson, 1987).

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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 Spring 1993 to Spring 1995. The sociological characteristics of the sample and the study site are presented in Table 1. See book's website *http://www.rapidintellect.com/SI-2001.htm*

We assigned intact classes as treatment or control because it was not possible to randomly assign students. 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 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 Spring 1993 to Spring 1995, except for Fall 1993 when 2 sections of each algebra type were designated as treatment. On the first day of classes, students in the college receive 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; 1986), and Chickering and Gamson (1987). Figure 1 provides a summary of specific components of instruction as applied in this quasi-experimental study.
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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 (i.e., textbooks, worksheets, and tests). In addition to the standard textbooks, the treatment classes also 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) 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 and 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 (Rosenshine, 1983; Rosenshine & Stevens, 1986). Students arriving late for class were not granted additional time for the quiz. The time allotted to the quiz was 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 encouraged to use it for further review at home.

Item analysis of each quiz permitted the identification of weaknesses and of 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; for example Rosenshine and Stevens (1986) suggested "guided practice should continue until a success rate of 80% is achieved"(Rosenshine & Stevens, 1986, p.379). However, using standard deviation statistics to diagnose "class splitting" and responding with cooperative learning seems to be new. After the cooperative learning took place, the concepts were included in a quiz where mastery was again tested. In addition to quizzes, students were also given several longer tests and a final examination. In all project classes and on all tests students were graded on an absolute scale No. 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, they 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 in 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: 1) the percent of students who completed the class i.e., retention, 2) students' performance in mathematics, and 3) 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 in the period of the study.

Since the institution where the study was based does not mandate common final exams2, we were not able to measure directly measure the mathematics performance of the treatment students 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 followed by a post-test version at the end of the semester3. 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, six 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 six 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

The treatment classes lost an average of 6.7 students from the second week to the end of the semester 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. Dividing the sample into elementary and college algebra, for the control groups the standard deviations were 12% and 13% respectively whereas for the treatment classes it was 4% for both. This indicates that the variation in retention rates may be independent of the class taught, but dependent on whether the classes belonged to the treatment or the control group. Table 2 provides specific details on the retention component of the project. See book's website *http://www.rapidintellect.com/SI-2001.htm*

Mathematics Performance

The treatment group scores on the final exam (mean=70; SD= 22) were not statistically different ($t=0.29$, $p > .20$) from that of the control group of students (Mean=68; SD=14) from a 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 in high-school mathematics.

Ability to Work with Full Concentration

Arithmetic cut time results. The arithmetic skills tests used to test for concentration skills covered material which was at a lower level than the material taught in any of the classes (treatment or control). For that reason, students were only given 20 minutes to complete the pre- and post-tests despite the College Board's recommendation of 30 minutes. Table 3 provides the results for both the treatment and the control classes. Although the treatment and control group pre-tests were statistically equal (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 3 also displays the reading comprehension gains for all treatment classes. Since the percentile scores shows the relative position of the students among their peers in the U.S., 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. Note that the pre-test standings (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.
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Effects on students with different ability levels. We wanted to find out whether the effect was extended to both strong and weak students. We therefore divided the students into four groups according to their pre-tests. Table 4 reports the results of each quartile in both the arithmetic and reading comprehension. There were significant percentile improvements by students at each level of competence.
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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 non-significance of the comparison between the treatment and the control students (from the Research I university) is very important to this study. It could easily be argued that the control group was much better prepared than the 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. 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 3, 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 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 percent as shown in Table 5. The students in the top 75% achieved very large gains, but without a significant increase in their scores' standard deviation. 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.
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Limitations and Implications

The present study has several limitations. As indicated earlier a true experimental design was not possible. Secondly, 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. This 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 the 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 (Hiemenz & Hudspeth, 1993; Garland, 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 the present study further suggest that adjustments in teaching methodology in mathematics can result in gains not only in mathematics but also 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 from testing. Testing should be viewed as a form of teacher-student dialogue and as such, a formidable educational tool.

Y. Sagher, University of Illinois at Chicago
M.V. Siadat, Richard J. Daley College
Linda Serra Hagedorn, University of Southern California