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ABSTRACT

During the academic years 1993-1995, instructors from the Department of Mathematics from the University of Illinois at Chicago and Richard J. Daley College (Illinois) conducted an experiment in remedial mathematics classes at a community college. The researchers wanted to investigate whether, while teaching mathematics in a rigorous manner, they could also use their instruction to enhance the students' academic and workplace skills. Remedial mathematics constitutes a large part of the curriculum in postsecondary institutions across the U.S. In a national study of college-level remediation in 1990, it was found that 21 percent of all entering college freshmen were enrolled in a remedial mathematics course. The project used mathematics classes to enhance the student' work and study habits and improve their concentration skills. This, in turn, produced good results in mathematics, and greatly improved the students' reading comprehension scores. Their general experience as educators had convinced them that unsuccessful students are held back by behavior patterns which inhibit learning. In their program, they addressed the behavior patterns of students in various ways. For example, to increase the students' attention spans, they administered time-pressured quizzes, which required work done with full concentration. (Contains 46 references.) (JA)

Building Study and Work Skills in a College Mathematics Classroom

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"Have you noticed, too, how people with a talent for calculation are naturally quick at learning almost any other subject; and how a training in it makes a slow mind quicker, even if it does no other good?" Plato, The Republic.[1]

ABSTRACT:

During the academic years 1993-1995, we conducted an experiment in mathematics classes at a community college located in a metropolitan city in the United States. We used mathematics classes to enhance the students' work and study habits and improve their concentration skills. This, in turn, produced good results in mathematics, and greatly improved the students' reading comprehension scores; as Plato had observed, mathematics can be a universal educational tool.

INTRODUCTION:

Remedial programs and, in particular, remedial mathematics, constitute a large part of the curriculum in post-secondary institutions across the U.S. In a national study of college-level remediation conducted in 1990 by the U.S. Department of Education, it was found that 21 percent of all entering college freshmen were enrolled in a remedial mathematics course (Mansfield et al., 1991). Another U.S. Department of Education report surveying the course-taking patterns over the two-decade period, 1972-1993, showed that 46 percent of college students with more than 10 hours of credit had taken at least one remedial course in mathematics, English, or basic study skills. Although this rate had remained flat over the time span in the study, the average number of remedial courses taken by these students had actually increased (Adelman, 1995). Young (1993), gives data showing that more than 15 percent of mathematics registrations in colleges and universities in the U.S. in Fall 1990 were in remedial classes and more than 50 percent were in courses below calculus level.

[1]Francis Macdonald Cornford translation, Oxford University Press, 1945.

Even at leading mathematics departments in the country (Group I, American Mathematical Society classification), remedial mathematics constituted 9 percent of the undergraduate enrollments in mathematics in Fall 1995, and pre-calculus an additional 14 percent (Fulton, 1996).

At community colleges, remedial mathematics constitutes a large part of the the mathematics course offerings. Enrollment in remedial courses at two-year institutions climbed from a third of the total mathematics program enrollment in 1970 to more than half in 1990. In this period, ".....remediation was classified as a major problem by 65% of [mathematics] department heads" (Watkins et al., 1993. p. 56).

At the college where this study was conducted, remedial mathematics constituted 62 percent of all mathematics registrations in the Fall 1995 semester. Overall, 91 percent of all mathematics registrations in Fall 1995 were in courses below the level of calculus.

How effective are college-level remedial courses in mathematics? Young (1993) writes "Remedial mathematics does not remediate; few people taking college algebra complete more than one semester of calculus....." (p. 1334). Another indicator of the problematic nature of remediation at the postsecondary level is given by Adelman (1995): "The proportion of grades indicating Withdrawal, Incomplete, and No-Credit Repeat has nearly doubled since the 1970s. This increase is heavily concentrated in remedial courses and in mathematics below the level of calculus" (p. x).

Clearly, there is a continuing crisis in the teaching of mathematics at secondary and postsecondary levels in this country: High schools graduate a large number of students unable to begin college-level mathematics and colleges struggle with the teaching of remedial mathematics. Moreover, a lack of proper education in mathematics has become a limiting factor for the professional aspirations of a very large number of young people; many professions have a prerequisite of college mathematics, others use college mathematics as an educational sieve. Most importantly, the need for successful remediation in mathematics frequently is but one symptom of the need for general educational remediation.

Remedial education in college and, in particular, remedial mathematics education, requires a special focus. Students in remedial mathematics classes are not those who simply do not know elementary mathematics and need to learn it. These students all have attempted to learn mathematics in the past and in one way or another have not been successful. This has important implications. Teaching the material as one would teach it to middle and high school students is likely to fail: it has failed these students before. Moreover, past failure has left its marks on all remedial students. Their emotional response to the material is very different than that of the students exposed to it for the first time. Anxiety and low self-esteem have replaced natural curiosity.

Remedial college students are, generally, an older population of students. They are no longer a captive audience; they can choose their teacher or class or the method of instruction. They need to be convinced that a proposed model of instruction actually works for them and that they can be successful at it. Whereas middle and high school students can be motivated by discovery projects, remedial students are best motivated by the prospect of success. This success has to be real: they are quick to recognize and dismiss remedial programs which give them the appearance of success, high grades, without truly addressing their deficiencies.

As described below, we devised and implemented an assessment-directed teaching program, incorporating frequent feedback and additional instruction focused on the students' difficulties. While teaching mathematics our method also educated the students to work quickly and accurately, with full concentration.

We measured the outcomes in both aspects of our work, the performance of the students in mathematics and their increased ability to concentrate on a task. Our measurements of students' outcomes include 12 experimental and 4 control classes. The evaluations show not only excellent performance by the students in the project classes in the subject matter, algebra, but also greatly improved concentration skills. Finally, although we demanded performance at a far higher level than in other sections of the same classes, the dropout rate in the project classes was below the average of the other sections.

This project was carried out while one of us taught regular classes at the college. Naturally we could not isolate new ideas and techniques in the instruction to measure their specific effects - - the students were entitled to our best efforts in all aspects of instruction. We describe below the entire instructional program and give our reasoning for its various aspects, but ask that the reader pay special attention to time-pressured work and the discussion of its role in the learning process. We also note our underlying belief that the teaching of mathematics, even in a remedial class, is part of the general educational process and should be measured and evaluated not only with respect to the particular subject matter being taught but also in its effects on the students' general skills.

We believe that one of the most important skills students should acquire in school is the ability to work with full concentration. Students who can work with full concentration will do well in mathematics, in other subjects, and indeed will carry an invaluable skill for the rest of their professional lives. Through our teaching, testing, and classroom regime, we sought to help students build their concentration skills.

DESIGN OF THE INTERVENTION:

Conceptual Framework:

We wanted to investigate whether, while teaching mathematics in a rigorous manner, we could also use the instruction to enhance the students' academic and workplace skills. We have not been able to find literature addressing this question.

The first step we took to implement our program was to identify the causes of the students' lack of success in mathematics. Our general experience as educators had convinced us that unsuccessful students do not lack intelligence or a desire to succeed. Rather, they are held back by behavior patterns which inhibit learning. This hypothesis is buttressed by other researchers (Meyer, 1972; Hodges, 1981; Morgan & Jenson, 1988; Fad & Ryser, 1993; Robinson, 1994).

The destructive behavior patterns of unsuccessful students include:

(a) Short attention spans; the inability to concentrate on a task for more than a few minutes (Horn & Packard, 1985; Soraci, Jr., et al., 1986; Lee & Meyer, 1994).

(b) Little or no attention to assigned homework (Keith, 1982; Vratanina, 1988; Robinson, 1994).[2]

(c) Short time horizons; deadlines more than a few days away are rarely acted upon (Solomon & Rothblum, 1984; Beswick, Rothblum & Mann, 1988).

(d) Failure to learn from mistakes; in particular, unsuccessful students do not use mistakes on an exam as guides for further study (Hodges, 1981).

(e) Passivity; the students hope to pass the class without being noticed and are therefore reluctant to ask for help (Hodges, 1981; Lee & Meyer, 1994).

(f) Poor attendance patterns (de Jung & Duckworth, 1985, 1986).

(g) Low self-esteem (Gill, 1969; Meyer, 1972; Calsyn & Kenny, 1977; Carr, Borkowski, & Maxwell, 1991).[3]

(h) Ignoring statements made by teachers.[4]

[2]The literature shows that regular attention to homework produces academic success. We chose to emphasize the logical conclusion that unsuccessful students failed to do their homework, since it underscores the problem we need to address.

[3]"The underachiever's inability to learn becomes a self-fulfilling prophecy. A circular relationship evolves in which the student's self-concept affects his school performance which, in turn, reinforces his existing self-concept." (Meyer, 1972, p. 66). Remedial students in post-secondary institutions are at the tail-end of this downward spiral.

[4]This observation corresponds to our experience and that of other teachers with whom we discussed our work. Unfortunately, there seems to be no literature which addresses this issue.

The last point challenges the teacher to find a way to communicate expectations and standards in a language which will register with the students.

Success in mathematics cannot be achieved without addressing these general educational problems. Moreover, these problems affect the student's work throughout the curriculum. Successful remediation in mathematics is therefore part of general educational remediation.

Any program which attempts to change long-standing behavior patterns in students has to provide them with quick and unambiguous results. It has to set high standards, while giving students the means to succeed, and a message of hope at each step. A typical college class contains students with different ethnic and cultural backgrounds. A program which integrates these students in a joint effort of remediation works best if it addresses all students with the same voice. Finally, the undertaking has to be important to the student. Mathematics responds to each of these needs. Mathematics is a very precise tool. Evaluation of performance in mathematics can be objective, accurate, and prompt. Mathematics is important as a discipline, and it is culturally unbiased. Through mathematics, one can achieve high standards of performance step by step, and each individual part can be rewarded immediately.

General Description:

In our program, we addressed the behavior patterns of students in the following ways:

(a) To increase the students' attention spans we administered time-pressured quizzes which required work done with full concentration.

(b) To encourage the students to do their homework we rewarded their work with success on the homework-based quizzes.

(c) We presented our students with frequent deadlines which would fall within their short time horizons.

(d) We encouraged students to learn from their mistakes by providing them with immediate feedback and repeating questions in the follow-up quizzes until the students achieved mastery in the topic.

(e) We encouraged active participation in the classroom by bringing students together through group work which promoted cooperation and peer tutoring.

(f) To address poor attendance patterns we issued administrative drops to students who missed three classes. Students could petition to be reinstated, but reinstated students were not allowed any additional absences.

(g) To address the students' low self-esteem we gave them well defined tasks, the tools to carry out those tasks, quick feedback for their attempts, and repeated success when they achieved mastery.

(h) To teach the students to take the teacher's statements at face value we applied a consistent code of behavior in the classroom, and gave repeated evidence that following the instruction produced success.

We viewed our students as partners in a goal-oriented venture, and required that they meet the standards of such ventures. To put it in terms familiar to the students, most of whom have had prior job experience, we said that we would apply to the mathematics classroom the "standards of a work place." This means a strict attendance code, quick and accurate completion of all assigned work. individual accountability for the quality of the work, and evaluation of performance according to absolute, rather than relative, standards.

These rules may seem harsh by current educational practice, but current educational practice has failed for students who are in a remedial class. They need another approach. When we bring to the classroom standards that the students understand and respect, we can bring out the best in each of them.

Materials:

The materials used in all experimental classes were standard college mathematics text books, and instructor-prepared problem sheets, quizzes and tests. All subject matter tests, quizzes, and the final exam were designed and prepared by the authors. The pre-tests and post-tests on arithmetic and reading comprehension were College Board's Descriptive Tests.

Calculators were not used in the project classes.

The students received more problem sheets, more quizzes, and more tests than students in regular classes. The additional work by the teacher required to write and grade the additional quizzes and tests was roughly balanced by greatly reducing the time spent on grading students' homework. See the sub-section on homework for more details. We did not provide the students any other additional educational resources: no additional office hours, no additional class time and no review sessions. Thus the results of our study can be compared with results achieved in classes run within current budget constraints.

Classroom Management:

Like most other week-day classes at the college, the project classes met twice a week, each time for 100 minutes. All class meetings began with a short period in which the teacher answered students' questions. This was followed by a multiple choice quiz. Tardy students missed some or all of the discussion. Students who showed up after the quiz had begun were allowed to take the quiz in the time remaining and had to stop their work at the same time as other students. Students who missed the quiz received a score of zero. Thus, the quizzes taught the students to attend class each time, on time. This policy clearly contributed to the students' success in our classes. If, as we hope, the new habits take hold, they will help the students across the curriculum, and throughout their professional lives.

The quizzes were partly based on the homework: with some exceptions, they were also cumulative.

Following each quiz, students' answer sheets were collected for processing but students were allowed to keep the question sheet as a guide for further review at home. Also, brief review of the quiz problems and their answers was provided immediately. The remainder of the class time was devoted to the teaching of new topics.

Computer scoring of the quizzes provided us with item analysis, information on class performance on each problem of the quiz. Topics on which the class scored poorly were repeated and amplified in the next quiz. The scoring also provided a descriptive statistical report on the class as a whole which was used to plan the next lesson.

An important part of the statistical report was the standard deviation of the scores on each quiz. When the standard deviation exceeded 25 per cent, we knew that the class was splitting: the top students were doing well and the weak students were still struggling with the material. In such situations the teacher is in a bind. One cannot continue to the next topic without losing the weak students nor can one re-teach the current material without boring the strong students. Our way out of this difficulty was cooperative learning, as described below. When as a result of cooperative learning the standard deviation declined to a more acceptable level, we resumed traditional teaching.

Quizzes and Tests:

Frequent testing has important educational benefits for the learner. It encourages regular study habits and discourages cramming (Mawhinney, et al., 1971; Dempster, 1992). It also reduces test anxiety (Dempster, 1992). Current research shows that students favor frequent testing (Bangert-Drowns, Kulik & Kulik, 1986, 1991).

Cumulative testing motivates the student to review older topics. Review of topics, done with the hindsight of later understanding, deepens the understanding of the earlier topics beyond what could be expected at the time these topics were introduced. Moreover, students, through the review process, improve their emotional response to the material. Earlier topics become old friends, helping the student master the new topics. Thus, cumulative tests result in higher levels of learning than tests related only to the contents of the last topic (Dempster, 1992).

Cumulative testing is particularly appropriate in mathematics instruction. Much more so than in other subjects, topics in mathematics depend on previous material, and students who are prepared to take a test on earlier material are also ready to utilize it in learning new topics. Of course the dependence on previous material extends beyond the most recent topics. Therefore the review of previous knowledge should include at least all topics taught since the beginning of the term.

The use of tests as a means to consolidate learning is well established (Dempster, 1992). Nungester and Duchastel (1982) conducted an important experiment comparing the performance of high school seniors who studied an essay on topics in British history. One group was tested immediately; a second group spent the amount of time used to test the first group, to review the material instead. A third group did an unrelated task in that amount of time. All students were examined two weeks later. The results showed a statistically significant advantage for the test group over the review group on exam items "that required recall or recognition of the same information as requested on the initial test." On items on the second test which had not been included on the first test, there was no statistically significant difference between the two groups. Both groups did significantly better than the control group, however. The authors conclude that testing is preferable to review as a way of consolidating knowledge.

This conclusion is likely to be much stronger in mathematics than in history: mathematical knowledge is more cohesive, and better retention of knowledge on some items is more likely to help the students do well on other items. Also, the point of balance between the benefits of testing and of reviewing is likely to shift even further in favor of testing when applied to students in remedial classes, rather than to successful students: students in remedial classes are likely to have fewer study skills and so are less able to utilize the review process.

The beneficial effects of examinations following closely upon the instruction is supported by an important study (Spitzer, 1939). Students in 6th grade in 91 elementary schools in Iowa read an article and were tested on its contents. Testing was more effective in improving content retention if the initial test occurred 1 or 7 days after the reading. The author concludes that immediate recall in the form of a test is an effective method in improving the retention of learning and should be employed as an educational tool. Moreover, Spitzer found that students who scored in the lower one third of the class in the initial testing have a more rapid initial rate of forgetting. Thus, for weaker students an examination to consolidate the learning should be given earlier rather than later.

At each class meeting, we administered a quiz or a test which were designed in a five-answer multiple choice format. With few exceptions which we discuss below, quizzes and tests were cumulative, covering the material from the beginning of the semester. They were also time-pressured.

We viewed quizzes as communications between students and teacher. The quizzes demonstrate the teacher's expectations and standards. The students' performance on the quizzes tells the teacher what the students know and which topics need additional attention, when the class is splitting, and when a large number of students have given up on particular topics. Students pay attention to what the teacher says through the quizzes. When these messages are frequent and clear, the students are able to respond and meet the teacher's expectations.

The quizzes motivated the students to study regularly, to review the material continuously and to cooperate in group study sessions and learn from their mistakes. We also used the quizzes and the tests to educate the students to work with full concentration. At the level of our courses, this meant working fast and accurately.

Slow work, we believe, is not uniformly slow but rather is the result of the intervals of work at normal speed interspersed with intervals of meandering thought. These interruptions in focused thought, we believe, are the cause not only for low output but also for what students call "stupid mistakes," mistakes of inattention. By requiring speed and accuracy on quizzes and exams we helped the students to eliminate periods of meandering thought and taught them to stay focused on the task at hand. The students' great increase in speed strengthens our belief that slow work is but fast work which is frequently interrupted.

We find this an extremely important question. If slow thought, in normal students, can be accelerated by the simple devices we used in our project, then many more students can achieve high professional standards. Even at the highest level, intellectual work is to a large extent seeing connections, having ideas collide. The fuller the concentration, the faster these ideas are moving, the more likely it becomes for the ideas to connect.

In addition to the quizzes, we administered several longer tests and a final examination. The role of the tests was not the usual one of motivating the student to review the course material as a whole; this we achieved through the cumulative quizzes. We used the longer tests to extend the time period in which the students were able to work with full concentration, beyond the limits of shorter quizzes.

We mentioned before that in some circumstances we gave quizzes which were not cumulative. These were one-topic quizzes which were used as a response to a particular behavior of students in the class.

Most teachers are familiar with the phenomenon of students deciding that certain topics are hard, and dropping their efforts. This happens more frequently in remedial classes than in regular ones. Students with low self-esteem do not view themselves as potentially "A" students. Rather, they are satisfied with a "C", which means scoring 70 percent on the test. They have what we call a "30 percent bin" to which they consign topics which they find hard, and plan to earn their

70 percent on other topics. We recognize that this is happening when the item analysis shows stagnant scores on particular topics.

Beyond the obvious point that the students frequently put more than half material in the 30 percent bin, this behavior is antithetical to remediation. An important goal for us was to restore the students' mathematical self-confidence. Having topics classified as hard, and dropped, cannot be part of the solution for these students. Our way of telling the students that no topic should be neglected was to give them - - when the item analysis indicated - - a one-topic quiz. Thus students who planned to pass the class without learning, say, word problems, were faced with a quiz consisting of only word problems. These quizzes were accompanied by group work sessions to give the students the means to succeed, but the dedicated quizzes were repeated until the students performed at an acceptable level in the topic.

Effect of Testing on Recall:

Dempster (1992) explains the benefits of testing closely following instruction as follows: Testing early helps the students do better on the test which produces better self-efficacy by the students. and this promotes later success. We propose an alternative explanation.

There is a considerable body of work on the effect of emotions on long term memory. Interesting research by Kleinsmith and Kaplan (1963, 1964), showed that whereas work in a low arousal state produces better short term recall, work in a high arousal state - - such as in a test - - produces far better long term memory. More recently, important research by Cahill, et al. (1994. 1995), identifies a biological mechanism responsible for enhanced long term memory associated with emotional arousal.

The phenomenon described by Kleinsmith and Kaplan: Low emotional arousal is better for short term recall and high emotional arousal is better for permanent memory, has important implications for the classroom. When new material is presented and needs to be recalled immediately as it is organized in the student's mind, a low arousal state is preferable. In the second stage, when the organized material is consolidated in permanent memory, work in a high arousal state is called for. This is when the quiz is most effective. Waiting to the end of the chapter for the exam, greatly diminishes the effectiveness of the exam as a consolidating agent for learning. In our judgement, the right time is the class meeting following the one in which the material was taught, after the students used the homework to organize the material and had the opportunity to ask for clarifications, but before new material is presented.

In our project, time-pressured tests and quizzes taught the students to work with full concentration. Moreover, time pressure challenged the students to mobilize their intellectual resources in the same way that athletic competition promotes the mobilization of physical resources. The quizzes and tests became exciting and challenging experiences. These shared intense experiences promoted social interaction in the class, which we believe was part of the reason for the very high level of cooperation between the students and the low attrition rate.

Grading Curve:

In many educational situations, students are evaluated relative to each other, on a curve. This does not educate the students to meet standards and strive for excellence. Students get a wrong message: you don't have to be good, just be better than the average. In the words of Bishop (1995): "American students, who expect to be graded on a curve, often wonder what difference it makes if they learn more or less."

As could be expected, grading on a curve also discourages cooperation (Halley, et al., 1973). One can not expect students to work against their self-interest by helping others do well, raising the average which then lowers their own grades. "It seems to me that sound educational policy does not put students in competition with one another. Sound policy puts them instead in competition with standards of excellence." (Gold, 1966). In the context of remedial education, grading on a curve is particularly harmful. Students with a history of low achievement are congregated in classes where the curve is set to ever lower standards as it is adjusted to the low performance in these classes. A large number of students in remedial classes meet the requirements set by the low curve and are promoted from one class to the next even as they lose their grip on the learning. Moreover, getting a B "on the curve" with a score of 62 percent sends a confusing message. These students, even more than successful ones, need a clear feedback: Getting 62 percent is a D, which means you have to work harder.

However, even a teacher who is committed to an absolute grading scale, may be using an implicit curve. When writing an exam the teacher makes decisions about the number of questions, and their level of difficulty, which would make the exam appropriate. This decision could be heavily influenced by the teacher's expectation of the performance of the students. Thus, even if we eliminate conscious relative grading, we still have an implicit curve guiding our testing. In our project we controlled this effect by having the author who did not teach the class (Y.S.) make the final decisions on the make-up of the exams. In general, we advocate using item banks which would include data on past performance of students on each item so that the implicit curve be replaced by an explicit historical curve.

In all project classes and on all tests our students were graded on an absolute scale: 90-100% for A, 80-89% for B, 70-79% for C, 60-69% for D, and 0-59% for F. No partial credit was given on any quiz or test; only correct final answers earned credit. The students were told that they are not competing with each other; they were encouraged to cooperate in order to achieve high standards.

Cooperative Learning:

Cooperative learning is an established educational tool. It promotes student motivation, builds group skills, and fosters social and academic interaction among students (Slavin, 1983, 1990, 1995; Johnson & Johnson, 1989; Sharan, 1990; Davidson, 1990). Students who participate in cooperative learning are also more likely to attend class regularly (Slavin, 1990, 1995). Of course, regular attendance promotes retention. We have also observed that academically successful students became leaders in our classes. This can be explained by the fact that these successful students helped others in the class. Cooperative learning made academic success a positive social attribute.

In our version of cooperative learning, groups of four students, one from each quartile of the class, worked on a problem sheet. The problem sheet had been written to address the weaknesses of the students. The students sat in circles, working individually on their problem sheets. They were encouraged to discuss their work with others in the group. The teacher moved between the groups, answering questions after they had been discussed within the groups. In this way, strong students were operating at a higher level, as teachers, articulating their understanding. Weaker students learned not only the material but also the way successful students operate.

The group work was followed by a quiz. The quiz was directly linked to the problem sheet and so the students' cooperative effort was rewarded immediately. The students were graded individually. In our classes group learning did not diminish each student's responsibility for learning.

For all its benefits, group work is appropriate for some class conditions but not for others. When the students are more or less at the same level of performance, a regular class is a more efficient way of teaching new material. Therefore when, as a result of group work, the standard deviation in the project classes dropped to about 18 percent we reverted back to traditional teaching. The choice of a standard deviation of 25 percent to start group work and 18 percent to halt it, represented a compromise between our desire to address all students in the class and the need to cover the curriculum. In a setting where the pace of the curriculum is slower, for example in a high school, we would probably use lower thresholds which would lead to more extensive use of group work.

Homework:

Homework serves to reinforce the students' learning (Foyle & Lyman, 1989), to provide feedback to the students. and to provide feedback to the teacher. Numerous studies have shown that homework increases students' achievement for all levels of ability (Keith, 1982; Paschal, et al., 1984; Foyle & Bailey, 1986).

However, reading the homework, writing notes on the students' papers and taking notes for the teacher's use, are time consuming tasks. A conservative estimate of the amount of the teacher's time needed for these tasks is 15 minutes per student, per week. A community college teacher typically teaches 4 classes, totaling 140 students. This means that if all students hand in their homework, and if the teacher does a conscientious job of it, the teacher spends 35 hours per week grading homework. It does not happen, of course. Many students do not hand in their homework. and many teachers check-mark the papers and give credit for the work without judging the output. There is little, if any, feedback. Many students are not given the opportunity to learn from their mistakes. The teacher does not find out what parts of the material the class finds difficult. Moreover, getting credit for work rather than for outcomes is not a good lesson for the student: the teacher doing a superficial job at grading the homework is not a good role model. The usual way of dealing with homework is not a good education.

In our project students who failed to show improvement on successive quizzes were asked to show their homework. The homework was reviewed with the students, in depth. This helped establish a connection in the students' minds between completion of homework assignments and success. There was however no general collection of homework of all students in the class.

Quizzes, partly based on the homework and given at each class meeting, motivated the students to work regularly and provided feedback to the students and to the teacher. Students had to study and be prepared at all times. Of course the students could ask questions in class about homework problems, or get help during office hours.

The time saved in grading homework was used by the teacher to design and prepare quizzes which provided the students with an accurate evaluation of their performance. At the same time, the teacher received the information needed to adjust the pace and the content of instruction.

We believe that the point of balance between time spent on grading students' homework and time used in testing and assessment should shift towards the latter.

METHODS:

Subjects:

The college in which this study was conducted is a two-year community college in a large metropolitan city, serving a broad geographical area comprising neighborhoods of various ethnicities and economic backgrounds. Our project encompassed a population of students similar to the general population at the college.

In Table 1 we summarize the sociological profile of the students in the credit program at the college and in our experimental classes. The data for the college describes the population (N = 4679) in Fall 1995 semester (*Statistical Digest of the College*: Fall 1995). The data for students in project classes covers the sample (N = 332) from Spring 1993 to Spring 1995. The college data does not add up to 100 percent in some tables since it excludes students who did not respond to the questions.

Of the 332 students in the study there were 8 who participated in two project classes. Each participation of these students is counted as a separate entry in this and in all subsequent statistics.

Sociological Characteristics

	African-American	Hispanic	Non-Minority	Male	Female	Age	Employed
College	30%	32%	36%	39%	61%	26	59%
Project	30%	33%	37%	42%	58%	23	57%

Table 1

The data for the Non-Minority group at the College includes 33% Whites, and 3% Asians/Pacific Islanders which we chose to put in a single category. Native-Americans comprised 1% of the students in the credit program at the College, but none participated in the project.

The data on student employment includes both full time and part time categories. The students in the project classes who reported employment worked an average of 26 hours per week.

Another important characteristics of the student population is its educational background. We summarize the data in Table 2.

Feeder Institutions

	Chicago Public	Chicago Private	Not Chicago	GED
College	51%	19%	18%	9%
Project	56%	19%	19%	6%

Table 2

Students in the private schools category were mostly from parochial high schools.

The statistics on students in the college credit courses represents students in the day program as well as those in the evening and week-end classes. The project students participated in day classes only. This is the likely reason for the lower average age of the project students, as well as for the lower percentage of students with GED.

Design:

The project lasted two and a half years and covered 12 experimental classes. For measuring of the effects of the project on the students' work skills we used 4 control classes. The project encompassed 2 classes (one in elementary algebra and one in college algebra) in Spring 1993, Spring and Fall 1994, and Spring 1995. In the Fall semester of 1993, the project had 4 classes

(2 elementary algebra, and 2 college algebra). The data from the 4 control classes (again 2 elementary and 2 college algebra) was collected in Fall 1993. All project and control classes were in the day program.

There was no pre-selection of students and the college class schedule did not identify the project classes. Students took these classes as part of their regular programs. However, on the first day of class, a policy statement was distributed to all students, informing them of the nature of the project and our expectations and ground rules. There was no unusual switching of sections by the students.

For measurements of the effects of the project on retention rates, we used 40 control classes, as explained in the discussion of retention.

RESULTS:

There are three components to our results:

(a) Retention. i.e., the percent of students who completed the class.

(b) Students' performance in mathematics.

(c) Students' ability to work with full concentration.

We did not measure the effects of the program on each of the 8 behavior patterns of unsuccessful students. Some of these were clearly affected. Class attendance was excellent, the students were active participants in the classroom, homework was done in a regular fashion, and as was clear from the end of semester interviews, the students' self-esteem was greatly improved. However. an itemized measurement of each of the 8 components, and more interestingly the persistence of the improvements of each item beyond the period of instruction, would be fascinating topics for further study.

Retention:

We measured retention by taking the official second week class size report of the college as the starting point, and the last week's report as the endpoint. We did so for the 12 project classes and for a control group of all other (N = 40) weekday mathematics classes of the same level in the period covering Spring 1993 to Spring 1995. We excluded from the comparison evening and weekend classes, since these classes serve a somewhat different population of students.[5]

RETENTION

		Begin	End	Change	Retention
Project	Mean	36.0	29.33	−6.67	81%
(N = 12)	SD	3.30	3.28	1.78	4%
Control	Mean	35.38	27.13	−8.25	77%
(N = 40)	SD	4.47	6.82	4.98	14%

Table 3

As seen in Table 3, project classes in the study lost 6.7 students on the average, while other classes lost 8.3 students. An independent z-test determining the significance of retention (proportion of students retained in each class) shows that the higher retention in the project classes is statistically significant at $\alpha = 0.05$.

The higher standard deviation of the retention for the control classes, 14 percent, compared to only 4 percent of the project classes, might be attributed to the variations in retention rates between different teachers in the control group. We therefore analyzed the retention rate of each teacher in the control group. We found the lowest standard deviation to be 8 percent. Thus the project classes had the smallest variation in the retention rate.

We also compared the standard deviations of retention based on the type of class: elementary or college algebra. For the control group, these figures were 12 percent and 13 percent, respectively. For the project classes, the figure was 4 percent for both types of classes. We can conclude

[5]The retention rate for all other 63 mathematics classes of the same level, including evening and weekend classes, was 75%.

that variation in retention rates was independent of the type of class taught, but dependent on whether the classes belonged to the project or the control group.

The higher retention in project classes was attained while the students had to work very hard, were tested at each class meeting, and were graded on an absolute scale, not on a curve, without receiving any partial credits. Moreover, although by mid-semester many students had a clear message, through quizzes, tests, and official mid-term grades, that they were not doing passing work, they still chose to remain in the class. This is particularly significant since the college has liberal drop policies: students are allowed to drop classes without any penalties, until 2 weeks before the end of the semester.

Performance in Mathematics:

Since parallel sections of mathematics classes at the college do not have a common final exam. we were not able to compare students' mathematics performance in project classes to that of the control classes.[6] We therefore gave a final exam of one of our college algebra classes, administered to 30 students in Spring 1993 semester, to a class of 12 students in the Mathematics Education program at a large Research 1 public university. Table 4 presents the results based on the scale 0-100 (raw score). The test of homogeneity of variance between the two classes showed no statistically significant difference between the standard deviations. (F-test for independent samples with F = 2.47 (F-critical = 2.57 at 0.1 level of significance, for 29 and 11 degrees of freedom)). The difference between the average scores of the two classes was not statistically significant either. (Independent t-test with t-value = 0.29 (t-critical = 1.303 at 0.20 level of significance, for 40 degrees of freedom)).

[6]Each member of the mathematics faculty chooses his/her own text book and gives his/her own final exam.

Performance in Mathematics

	Mean	SD
Project (N = 30)	70	22
Control (N = 12)	68	14

Table 4

When comparing the results, it should be kept in mind that the students in the control class were seniors in the Mathematics Education program, training to teach high school mathematics. They were one semester away from student-teaching. As we write today most of them are teaching mathematics in high schools, probably the very material of the exam.

These pre-service teachers are highly self-selected. They must have been successful in high school mathematics, since they chose to make the teaching of it their life work. They also have had many more courses in mathematics than the students in the project class: One semester of Trigonometry, three semesters of Calculus, and most of the following subjects: One semester of Analysis: one semester of Abstract Algebra, and one of Linear Algebra; Geometry, both Euclidean and Projective. And yet, the highest score in the teachers' class was 84%, achieved by 1 student; 9 out of 30 students in the project class scored 85% or higher.

The students in the teachers' class had a week's notice of the exam and were told that it will be on college algebra. The correlation between the scores of the students in the teachers' class on this exam and their scores on the course final exam, 73%, shows that the college algebra exam was well correlated with their work in the class.

The comparison with this self-selected, motivated, and educated group, leads us to conclude that the project class had mastered the material.

Ability to Work with Full Concentration:

We consider the students' improved ability to work on a task with full concentration as the most important outcome of our project.

We measured the students' ability to work with full concentration by their performance on arithmetic and English comprehension tests. At the beginning of each semester, and for each of the classes, we administered two pre-tests, one in arithmetic and the other in reading comprehension. At the end of the semester, we administered different versions of the arithmetic and English comprehension tests, as post-tests.

Arithmetic pre-tests and post-tests were versions (Forms M-3KDT and M-3LDT, which we refer to as forms K and L) of 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 questions which were in a four-answer multiple choice format and carried the same weight. The designated time (full-time) allowed for the completion of each version of the test was 30 minutes.

English comprehension pre-tests and post-tests also were versions (Forms K and L) of 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 questions which were in a four-answer multiple choice format and carried the same weight. The designated time (full-time) allowed for the completion of each version of the test was 45 minutes.

Although the Arithmetic Skills test covered material which was at a lower level than the material taught in the project classes, we surmised that the students would show great improvement on this test. We were concerned that the full extent of the improvement would not show up in the post-tests, as students would finish their work in much less time than the 30 minutes given by the College Board. We therefore administered the Arithmetic Skills exams in cut-time. We allowed the students 20 minutes both in the pre-tests and in the post-tests. Since we expected a smaller improvement in the English Comprehension tests, we administered the corresponding pre-test and the post-test in the time allowed by the College Board, 45 minutes.

In all classes, the English tests followed the arithmetic tests, with a 10 minutes rest period between the two. Also, to correct for the possibility that one of the two versions of the exams (forms K and L) would produce higher results, we administered forms K as pre-tests and forms L as post-tests to 6 of the classes, and reversed the order for the other 6 classes.

To compare the results from the two versions of each test (one given as pre-test and the other as post-test), we used the College Board's tables which give the percentile standings compared to a national sample of college and university students, for each of the arithmetic and English comprehension tests.

To establish the significance of the data for the gains, we applied dependent t-tests at the $\alpha = 0.01$ or $\alpha = 0.001$ levels of significance. For the significance of standard deviation changes, we applied dependent t-tests each for the given value of the pre-test, post-test correlation coefficient, r, at the $\alpha = 0.05$, $\alpha = 0.01$ or $\alpha = 0.001$ levels of significance. The results of the t-tests are included in Tables 5 through 17.

(a) Arithmetic Cut-Time Test:

In Table 5 we have the percentile standing on the arithmetic test (in cut-time) of students in the experimental classes. The increase in the average percentile score, over 21 points, is large and statistically highly significant.

We administered the pre-test and the post-test to 4 control classes in Fall 1993 semester. The results are shown in Table 6. A test of the homogeneity of variance shows that the standard deviations in the pre-tests, 24.46 for the control classes and 25.38 for the experimental classes, are statistically equivalent.[7] Also, the combined pre-test percentile score in the arithmetic test

[7]F-test for independent samples with F-value = 1.08 (F-critical = 1.80, at 0.01 level of significance, for 331 and 44 degrees of freedom).

in the control classes was 25.49 which is statistically equivalent to 24.17 of the experimental classes.[8] Thus the control group was well matched with the experimental group.

Percentile Scores in Arithmetic (Cut-Time) Tests for Project Classes

(pre-test/post-test correlation r = 0.75)

N = 332	Pre–test	Post–test	Change	t-value
Mean	24.17	45.87	21.71	19.89***
SD	25.38	29.89	19.80	4.51***

***significant at $p < .001$

Table 5

Percentile Scores in Arithmetic (Cut-Time) Tests for Control Classes in Fall 1993

(pre-test/post-test correlation r = 0.83)

N = 45	Pre–test	Post–test	Change	t-value
Mean	25.49	24.49	−1.0	-0.47^{ns}
SD	24.46	24.77	14.30	0.15^{ns}

ns (not significant at .05 level)

Table 6

[8] Independent t-test, based on the homogeneity of variance, with t-value = −0.33 (t-critical = −2.576 at 0.01 level of significance. for 375 degrees of freedom).

We also compared the arithmetic results of the students in the control classes with those of the students in our project classes in the same semester, Fall 1993. Table 7 shows the results for the project classes.

Percentile Scores in Arithmetic (Cut-Time) Tests for Project Classes in Fall 1993

(pre-test/post-test correlation r = 0.73)

N = 101	Pre–test	Post–test	Change	t-value
Mean	23.68	43.51	19.83	9.95***
SD	23.89	29.24	20.02	2.96**

***significant at $p < .001$; **significant at $p < .01$

Table 7

Again the assumption of homogeneity of variance between the two groups holds.[9] Also, the average pre-test arithmetic score, in percentiles, for the 4 project classes, 23.68, is well matched with 25.49 in the 4 control classes.[10]

The percentile change of nearly 20 points for the experimental classes is large and statistically highly significant. The results clearly show that the improvements in the performance of our students was due to their participation in the project classes.

[9] Independent F-test, with F-value = 1.05 (F-critical = 1.94 at 0.01 level of significance, for 44 and 100 degrees of freedom).

[10] Independent t-test, based on the homogeneity of variance, with t-value = −0.42 (t-critical = −2.576 at 0.01 level of significance, for 144 degrees of freedom).

(b) Reading Comprehension (Full-Time) Test:

While we did not teach arithmetic in the algebra classes, students may well have carried over some added competence in arithmetic from these classes. The results of the English comprehension tests are a more pure measure of the ability to concentrate.

Table 8 displays the English comprehension full-time gain for all experimental classes. Since the percentile score shows the relative position of the students among their peers in the U.S., the increase of 12.3 percentile points in the English scores means that in 15 weeks our students leaped over one-eighth of their peers.

The results of the control classes, presented in Table 9, show that the students' improved scores in English comprehension were due to their participation in our project classes, where no English was taught, and not to their participation in other college classes during the semester between the pre-test and the post-test.

A test of the homogeneity of variance shows that the standard deviations 29.07 for the experimental classes and 27.18 for the control classes are statistically equivalent.[11] The pre-test percentile standing, 45.4 for the experimental classes and 44.8 for the control classes, are also statistically equivalent, reiterating the fact that the groups were well matched.[12] The decline of over 12 percentile points in the average performance of students in the control classes is statistically significant.

[11] F-test for independent samples, with F-value = 1.14 (F-critical = 1.80 at 0.01 level of significance, with 331 and 44 degrees of freedom).

[12] Independent t-test procedure, based on the homogeneity of variance, with t-value = 0.12 (t-critical = 2.576, at 0.01 level of significance, with 375 degrees of freedom).

Percentile Scores in English Comprehension (Full-Time) Tests for Project Classes

(pre-test/post-test correlation r = 0.87)

N = 332	Pre–test	Post–test	Change	t-value
Mean	45.36	57.67	12.32	15.7^{***}
SD	29.07	27.05	14.34	2.66^{**}

***significant at $p < .001$; **significant at $p < .01$

Table 8

Percentile Scores in English Comprehension (Full-Time) Tests for Control Classes in Fall 1993

(pre-test/post-test correlation r = 0.75)

N = 45	Pre–test	Post–test	Change	t-value
Mean	44.80	32.62	−12.18	-4.44^{***}
SD	27.18	23.94	18.40	1.26^{ns}

***significant at $p < .001$; ns (not significant at .05 level)

Table 9

Again we compare the English Comprehension results of the control classes with those of the project classes in the same semester, Fall 1993, when the control study was conducted:

Percentile Scores in English Comprehension (Full-Time) Tests for Project Classes in Fall 1993

(pre-test/post-test correlation r = 0.93)

N = 101	Pre–test	Post–test	Change	t-value
Mean	45.03	58.01	12.98	11.88^{***}
SD	29.51	26.86	10.98	2.55^{ns}

***significant at $p < .001$; ns (not significant at .01 level)

Table 10

The homogeneity of variance between the two groups is well established.[13] Also, the combined pre-test English comprehension score in percentiles for the 4 experimental classes, 45.03, is well matched with 44.80, of the control classes.[14]

The material in the arithmetic test is much more elementary than the material of the algebra class, and so the exam was not a subject-matter exam. The improvement in the arithmetic skills test, we believe, is due to three reasons:

1. Improved concentrations skills.

2. Transfer of mathematics skills from the class curriculum to lower level material.

3. An improved emotional response to mathematics at the end of a successful semester.

We believe that the improvement in the English comprehension scores was due only to improved concentration skills. There was no instruction of English in any of the project classes and

[13]F-test for independent samples with F-value = 1.18 (F-critical = 1.94 at 0.01 level of significance, for 100 and 44 degrees of freedom).

[14]Independent t-test, based on the homogeneity of variance, with t-value = 0.044 (t-critical = 2.576 at 0.01 level of significance, for 144 degrees of freedom).

the results in English comprehension in the control classes do not support a claim that these improvements were due to instruction which the students may have had in other classes during the semester.

Correlation Between Improvements in Arithmetic and Improvements in English Comprehension:

Participation in the project classes produced large increases in the students' achievements in arithmetic and English 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 0.001.[15]

Effects of the Program on Students with Different Initial Performance:

Many educational programs have the unintended effect of increasing the spread of the students; stronger students are better equipped to benefit from the special programs. Thus the increased mean achievement is often accompanied by an increased gap between the students. Our program acted differently. The results show that the benefits of our program extended to all students in the project classes.

One way of measuring the effect of the program on students at each level of achievement is to group students by their performance on the pre-test and report on each group separately. We divided the students into four groups according to their scores in the pre-tests in arithmetic when we measured the change in arithmetic scores, and in English when we measured the change in English scores. Group 1 consists of the 25 percent (N = 83) of the students with the highest scores on the respective pre-test. Group 4 consists of the 25 percent of the students with the lowest scores. The gains on the arithmetic (cut-time) exam for each group are summarized in Table 11.

[15] t distribution with t-value = 4.49 (t-critical = 3.291 for 330 degrees of freedom at 0.001 level of significance.)

Arithmetic (Cut-Time) Gain by Group

Group		Pre-test	post-test	Change	t-value
1	Mean	62.8	78.9	16.1	9.52***
(N = 83)	SD	17.9	17.5	15.4	—
2	Mean	23.3	51.3	28.0	11.98***
(N = 83)	SD	6.8	21.7	21.3	—
3	Mean	8.9	32.5	23.6	10.14***
(N = 83)	SD	3.5	22.4	21.2	—
4	Mean	1.9	20.8	18.9	9.02***
(N = 83)	SD	1.1	19.4	19.1	—

***significant at $p < .001$

Table 11

It is clear that the benefits of our program accrue at each level; there is a significant percentile increase for each group of students.

Observe also that the students in the lowest group did better in the post-test than the students in the third group in the pre-test. Students in the third group did better in the post-test than the students in the second group in the pre-test.

We also divided the students by their performance on the pre-test in English comprehension into 4 groups. Table 12 presents the English comprehension gains for each group.

English Comprehension (Full-Time) Gain by Group

Group		Pre-test	post-test	Change	t-value
1	Mean	84.40	88.82	4.42	6.95***
(N = 83)	SD	8.19	7.65	5.79	—
2	Mean	56.98	69.07	12.10	9.04***
(N = 83)	SD	9.03	14.28	12.20	—
3	Mean	30.24	43.19	12.95	7.79***
(N = 83)	SD	7.02	16.36	15.15	—
4	Mean	9.81	29.61	19.81	10.46***
(N = 83)	SD	4.94	17.34	17.25	—

***significant at $p < .001$

Table 12

As the figures clearly show, there were significant percentile improvements by students at each level of competence, with the lowest achieving students benefiting the most from our program.

The comparison between the increase of 19.8 percentile points for the bottom group and 4.4 for the top is perhaps not too significant: there is a ceiling effect for students who score at the 84.4 percentile in the pre-test. But the comparison between the improvement of the students in the bottom group and those in the third is very interesting. There was much room for improvements for both groups and yet the students in the bottom group improved 50 percent more than those in the third.

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 we saw in Table 5, the standard deviation in the arithmetic test for the project classes increased by 18 percent, as the mean jumped by close to 90 percent. The increase in the standard deviation was largely due to the unnatural compression of the scores of the bottom 25 percent 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 13.

Percentile Scores in Arithmetic (Cut-Time) Tests for the Top 75 percent

(pre-test/post-test correlation r = 0.71)

N = 249	Pre–test	Post–test	Change	t-value
Mean	31.67	54.77	23.10	17.99^{***}
SD	25.45	27.70	20.26	1.89^{ns}

***significant at $p < .001$; ns (not significant at .05 level)

Table 13

The students in the top 75 percent achieved very large gains, but without a significant increase in their scores' standard deviation. Note also that in the full-time version of the exam where the lowest 25 percent was not so severely compressed the standard deviation did not increase (see Appendix II). We can conclude that the spreading out of the bottom 25 percent of students in the post-test is the main factor in changing the overall standard deviation of the scores.

CONCLUSIONS:

Policy Implications:

The results of our work suggest that the mathematics class can be used as a universal educational tool. Students can be taught to work with full concentration even as they are taught the subject matter. Improved concentration skills, which are manifest in a topic as distant from mathematics as English comprehension, can serve as a foundation for general academic success and for a lifetime of professional work.

Educational institutions put a high priority on student retention, and rightly so. Our experience from this study shows that higher standards coupled with a teaching method which addresses the students' needs, lead to lower dropout rate. The results we achieved in fact understate the case. Students who have their academic self-confidence improved and who have acquired general academic skills, will do better in other classes leading to higher student retention for the institution.

We advocate that teachers view testing as a dialogue with their students. That they use frequent testing to communicate high expectations and to learn where the students need additional instruction. In other words, the tests should be used dynamically rather as a way of obtaining a snapshot of students' performance. Moreover, our experience in this project as well as the literature in both psychology and biology convinces us that work in a high arousal state, i.e., in tests, can have a very significant contribution to long term retention and learning.

We have used cooperative learning as an intervention when the performance of students in the class diverges. We strongly recommend this practice.

Further Research:

We recognize that one weakness in our research is that it has been conducted with one classroom teacher, albeit in 12 classes and over a two and a half year period. The most immediate task is to repeat the experiment on a larger scale.

Our students participated in the project 1 semester, 15 weeks. We could not continue with the them beyond that period, and it would be very important to find out how long students should work in this way to acquire stable habits which would persist under different circumstances. Once we find out the right amount of time for the students to work in this system, we would need to devise a transition to a more independent and creative learning by the students.

It would be very interesting to analyze the factors for the students' increased ability to focus on a task. Was it the result of newly acquired habits of controlling meandering thought, or were there also contributions by the students' increased academic self-esteem and lower anxiety levels during exams?

Could appropriately modified versions of our program be implemented in high school classes?

DISCUSSION:

The economic consequences of weak educational systems are widely recognized. "The National Alliance of Business, as part of its work as a member of the Business Task Force on Student Standards, has taken a strong position on the importance of all students mastering challenging academic subject matter, calibrated against world-class standards." (Goldberg, 1995).

But what is it about our educational system which makes it weak? Why does the present educational system graduate students who are unprepared for the work force? Obviously, it is not just Learning which the work place demands. but also learning skills, a work ethic, the ability to concentrate and work quickly and accurately, and the perseverance needed to bring each task to a successful conclusion; the ability to cooperate, while taking responsibility for one's performance.

In our project students were educated in these habits. Moreover, the classes in which the students acquired these skills were also very successful in teaching mathematics. The students learned to do mathematics fast and accurately; they were challenged to do more and build on their success. They could easily measure their success since it was quantified; they could also learn from their mistakes quickly, because they were provided with immediate feedback.

Success is the best motivation. Students in our project were shown a way to succeed: Learn the theory, practice to achieve mastery and work with full concentration, quickly and accurately. At the conclusion of each semester we conducted interviews with all students.[16] These interviews made it abundantly clear that the students in our classes were very happy with their success[17] and very eager to continue with their education. They felt that they now had acquired the knowledge and the skills which would serve as a basis for success in the future.

[16]To make it easier for the students to express themselves openly and freely, the interviews were conducted by Y.S. who was presented to the students as a researcher from a different university, without the presence of the instructor.

[17]In appendix III we quote student evaluations from two experimental classes.

APPENDICES:

We return to several topics which were mentioned before. but which were not discussed in full.

I. Speed and Performance:

Fast work, as emphasized in our project, should not be confused with fast learning - - which we did not insist on. Confusion between these two aspects of speed is common, and we should discuss it briefly.

Fast learning. which means learning new material in a short amount of time, with the least number of repetitions by the teacher, is sometimes an expression of student's concentration and intelligence. It could also be an expression of a student's willingness to accept the teacher's point of view and work with the new material without internalizing it. We, as most teachers of mathematics, have encountered a number of students who were slow to learn but who turned out to be superior to quicker students. These students needed additional time as they internalized the material. and that time was well spent indeed.

The speed we emphasized in our work was the fast application of ideas and techniques which the students had learned and were expected to have mastered. This helped our students acquire concentration skills, as we discussed in the paper. We believe that automatization of basic mathematical operations in the student's mind, and the resulting improved technical skills, greatly improve the student's emotional response to mathematics, and increase the probability that the student chooses to think about mathematical problems.

II. Comparison of Full-Time, Cut-Time Gains:

In the last two semesters (i.e., 4 project classes), we measured the students' performance in all tests in both cut-time and full-time. We did this in the following manner: Students received a red pencil and a blue pencil. In the arithmetic tests they were told to use the blue pencil in the first 20 minutes and switch to the red pencil for the last 10 minutes. The corresponding times for the English comprehension tests were 30 and 15 minutes. The improvements in the full-time scores were predictably somewhat smaller, but still highly significant.

Tables 14 and 15 present the percentile arithmetic standings in full-time and cut-time for the experimental classes.

Percentile Scores in Arithmetic (Full-Time) Tests for Project Classes Fall 1994 - Spring 1995

(pre-test/post-test correlation r = 0.83)

N = 116	Pre–test	Post–test	Change	t-value
Mean	34.91	51.73	16.83	10.18***
SD	30.67	30.34	17.80	0.21^{ns}

***significant at $p < .001$; ns (not significant at .05 level)

Table 14

Percentile Scores in Arithmetic (Cut-Time) Tests for Project Classes Fall 1994 - Spring 1995

(pre-test/post-test correlation r = 0.75)

N = 116	Pre–test	Post–test	Change	t-value
Mean	22.57	47.59	25.03	12.92***
SD	25.43	31.34	20.87	3.40***

***significant at $p < .001$

Table 15

As is seen, the gains in arithmetic were statistically significant in both cut-time and full- time intervals with higher gain achieved in the cut-time.

Tables 16 and 17 display the gains in English comprehension scores measured in cut-time and full-time for the experimental classes.

Percentile Scores in English Comprehension (Cut-Time) Tests for Project Classes

Fall 1994 - Spring 1995

(pre-test/post-test correlation r = 0.83)

N = 116	Pre–test	Post–test	Change	t-value
Mean	31.28	51.84	20.56	13.20***
SD	26.29	29.55	16.78	2.24^{ns}

***significant at $p < .001$; ns (not significant at .01 level)

Table 16

Percentile Scores in English Comprehension (Full-Time) Tests for Project Classes

Fall 1994 - Spring 1995

(pre-test/post-test correlation r = 0.89)

N = 116	Pre–test	Post–test	Change	t-value
Mean	45.98	61.77	15.78	12.08***
SD	30.38	26.33	14.08	3.36^{ns}

***significant at $p < .001$; ns (not significant at .001 level)

Table 17

As could be expected, there were also statistically significant gains in English comprehension for both cut-time and full-time intervals with higher gain attained in the cut-time.

III. In Their Own Words: Student Evaluations:

At the end of each semester. but before the final exam, M.V.S. gave the students the standard Student Evaluation Questionnaires of the College. The questionnaires are unsigned and so we cannot correlate the answers with eventual success in the class. We reproduce here the complete responses of all students in two of the classes (Math 110 and Math 140, Spring 1994) to one question. To maintain the authentic feel of the responses we did not correct either spelling or grammar errors. When the student's response to other questions shed light on his answer to the fixed question, we quoted this response as well.

The question is: What is the most useful and/or interesting thing you learned in this course? The answers are:

Elementary Algebra (Math 110).

1. How to calculate problems faster. (Added: Q. What did you expect to get out of this course? A. Refresh my memory and refine my math skills. Q. Did you get it? Explain. A. Yes. I received what I wanted out of the course and more. It improved my study skills. Q. Additional comments. A. ....This is the only math class I've taken and not be lost at the end of the semester.)

2. Review the time-tables. I had actually forgotten them. Interesting? there was nothing; it just a nice feeling in getting the right answer.

3. How to do word problems.

4. Concentration helps to succeed. That this course was fun + I did not expect that, I looked forward to class.

5. How to study.

6. everything.

7. Time skills. Study habits. (Added: Q. What did you expect to get out of this course? A. To learn more about math. Q. Did you get it? Explain. A. Yes, because math is my worst subject but I learned I could do it if I tried.)

8. Everything was useful but the time limits we had on test was good because everything we do evolves around time.

9. Math.

10. I relearned things about algebra that I didn't know in high school.

11. The techniques used to complete a math problem. (Added: Q. What did you expect to get out of this course? A. increase my math skills. Q. Did you get it? Explain. Yes, I improved on concentration, speed, and skill.)

12. Word problems.

13. How to make better use of time. More productive - able to use it in other courses.

14. Everything.

15. The Quadratic Formula.

16. Dr. Siadat wouldn't go on to a next problem until he was sure we had understood what we were working on - And I thought that was great.

17. That I dont understand word problems.

18. How to work out the problems faster.

19. everything.

20. the whole class was very interesting. (Added: Q. What did you like most about the course? A. that I can finally solve problems.)

21. I learned how to work problems out faster. (Added: Q. What did you expect to get out of this course? A. To learn more about math & be able to work problems faster. Did you get it? Explain. A. Yes. At first I didn't like the fact that you timed us for the tests, but now I realized it helped me concentrate more & do problems faster.)

22. The most useful and interesting thing I learned in this course was everything. Everything to me seemed very interesting and useful.

23. Timing. I now have a sense of timing because I can do things quicker.

24. If you are agressive and determine you can do whatever you want.

25. You can learn how keep up with Money. (Added: the student listed his/her major as Business.)

26. I learned to think fast to go over a problem and decide what needs to be done.

27. The most interesting thing I learned is that all people count no matter how intelligent they are.

28. Word problems.

29. The ability to answer problems faster.

30. I learned to do problems mentally. (Added: Q. What did you expect to get out of this course? A. I got more than I expected. Q. Did you get it? Explain. A. I became <u>much</u> better & <u>much</u> faster in math. Q. Additional comments. A. I enjoyed the class very <u>much</u>!)

College Algebra (Math 140).

1. The most useful & interesting thing I learned in this course was how to concentrate on what I'm doing and be efficient.
2. Mostly everything. (Added: Q. What did you expect to get out of this course? A. I expected a lot but I know I must also give a lot in order to expect. Q. Did you get it? Explain. A. Yes. At times I did have a little confusion but I just had to work at it.)
3. The way to study.
4. A way to study.
5. Learn to concentrate.
6. I found that I became efficient in my work. Performance + comprehension specifically.
7. The importance of dedication to studying and that repetition increases the memories (minds) ability to learn. I have taken studying more seriously than with previous classes.
8. Better study habits - Confidence that I could handle Math. The practice drill sheets were very helpful. (Added: The drill sheets were part of the group work.)
9. everything. But most of all is how to time myself and to do things right and also to try my best.
10. I learned that math is not as hard once you spend time learning the rules and concepts of it.
11. The whole lesson was especially knowing log terms. It was difficult when I saw it on exams & didn't know what it was. (Added: Q. What did you like most about the course? A. The

whole course, mainly taking quizzes every class period to make sure information was not forgotten. I like the idea if you don't do so good at beginning you always had a chance in the end.)

12. Maintaining my anxiety during tests. Increasing my computative speed. (Added: Q. Additional comments. A. As I walk out the door today I feel good about what I have learned in this class & the speed & accuracy I have achieved.)

13. that math isn't difficult if you put your mind to it.

14. To stay clam while taking a test. (Added: Q. Additional comments. A. This course helped me not to resist the numbers.)

15. To time my work faster.

16. the log.

17. I really learned how 2 do the quadratic formula.

18. Factoring/used in 141. (Added: Q. What did you expect to get out of this course? A. A better understanding of mathematics. Q. Did you get it? Explain. A. Yes. It's one thing for me to be able to do a problem with the aid of an instructor but its another to be able to just see and do it.)

19. Equations. (Added: Q. Additional comments. A. This is the best class I had in a long time, because you have a good time learning.)

20. The new explanations of problems. (Added: We believe that this refers to word problems.)

21. The whole semester was useful & interesting & enjoyable.

22. The quizes and the insparation of the teacher. (Added: In the last item, Additional comments: "...you really helped me understand word problems and not to be afraid of math.")

23. The whole course was intresting.

24. That to achieve in <u>any</u> course one must practice and practice until you understand and learn to do the problem correctly with no hesitation.

25. Perfect practice makes perfect.

26. Don't give up on word problems because they are important in the future. (Added: Q. What did you like most about the course? A. Whatever I failed in, it was brought to my attention until I learned it again. Q. Additional comments. A. Maybe I should had quit, but you gave me confidence & maybe I really should had drop, but I feel stronger in my life & studies.)

27. No response. (Added: Q. What did you expect to get out of this course? A. Confidence in doing Algebra. Q. Did you get it? Explain. A. Yes.)

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