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Fluency Training on Quantitative Skills Tested by the Graduate Record Examination

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FLUENCY TRAINING ON QUANTITATIVE SKILLS TESTED BY THE GRADUATE RECORD EXAMINATION

by

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This research consisted of an evaluation of a Graduate Record Examination (GRE) preparation course and two ancillary studies. Eighteen students enrolled in one of three courses (spring, summer, or fall) during which they spent approximately 140 hours preparing for the GRE using self-instructional texts and supplementary materials. Two sets of fluency practice drills with both accuracy and speed criteria were developed to improve students' performance on the quantitative portion of the GRE. The first set of four drills used in the spring and summer courses covered basic skills (basic math, fractions, decimals, and percentages). The second set of 42 drills, used in the fall course and subsequent studies, covered more complex skills (algebra and geometry) in addition to the basic skills. Standard self-instructional texts, were also used in all three structured, self-paced courses. In the same courses, students prepared for the verbal portion of the GRE by using a computerized flashcard program in addition to a self-instructional text.

Students in the three courses combined (n=18) had a mean improvement of 39 points on the verbal portion of the GRE, going from 417 (pretest mean) to 456

(posttest mean), and a mean improvement of 76 points on the quantitative portion of the GRE, going from 461 (pretest mean) to 537 (posttest mean). The mean improvement for the verbal and quantitative portions of the GRE combined was 116 points, going from 877 (pretest mean) to 993 (posttest mean). Based on results from the GRE-preparation courses and the ancillary studies, there were no clear differences in the effects of the two sets of fluency drills on performance as measured by the GRE.

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CHAPTER I

INTRODUCTION

In the United States, 64% of all graduate programs require or recommend submission of Graduate Record Examination General Aptitude Test scores (Educational Testing Services) as part of the admission process (Clark, 1986). This encompasses 57% of more than 7000 master's degree programs and 75% of almost 5500 doctoral degree programs (Clark, 1986). Frequently, excellent students -- those with a grade point above 3.5 on a 4.0 scale -- are denied entrance to the graduate program of their choice because of unacceptable scores on the Graduate Record Examination (GRE). The majority of universities that require applicants to take the examination consider a minimum of 1000 points an acceptable score, which is a combination of scores from the verbal and quantitative portions of the examination (e.g., University of Florida, West Virginia University, etc.). The analytical portion of the GRE typically is not used in the selection procedure.

The goal of this research was to create a preparation sequence within a GRE-preparation course that would increase the verbal and quantitative skill level of graduate school candidates in order to maximize their performance on the GRE and in graduate school. The procedures were based on those of previous versions of this GRE-preparation courses, with the addition of a component designed to develop fluency (speed and accuracy) with the quantitative skills represented on the GRE, the main focus of this research.

This chapter presents a review of the literature in five areas: (1) the predictive validity of the GRE, (2) preparation for the GRE, (3) methods of teaching remedial mathematics to various populations, (4) computer-based mathematical instruction, and (5) fluency instruction.

Predictive Validity of the Graduate Record Examination

Numerous studies address the issue of the predictive validity of the GRE (Ingram, 1983; Thornell & McCoy, 1985; House & Johnson, 1992; Goldberg & Alliger, 1992; Huitema & Stein, 1993; House & Johnson, 1993; Morrison & Morrison, 1995; Nilsson, 1995). Much of the literature reflects concern regarding the ability of the GRE to accomplish the goal of predicting the future performance of applicants in their respective graduate programs. The majority of these studies use the graduate grade point average (GGPA) as the criterion measure as it is the most common measurement of success in graduate school (Ingram, 1983).

In a review of ten studies focusing on the predictive validity of the GRE, Ingram (1983) found that in cases where the GGPA is used as the criterion variable, the GRE-Verbal (GRE-V) test correlated significantly in only 25% of the studies and the GRE-Quantitative (GRE-Q) test correlated significantly in only 12.5 % of these studies. Ingram notes that a more serious problem exists in addition to the lack of empirical evidence supporting the predictive validity of the GRE - the fact that the predictive validity of the GRE cannot be determined. Daws (1975) pointed out that since students must have high GRE scores to be admitted into graduate school, this creates a problem regarding the sample. As reported validity studies used subjects who have already been accepted to graduate school, the range of scores were restricted and the correlations have been attenuated.

Huitema and Stein (1993) addressed the issue of restriction of range by examining data from 138 students. In this particular case, all students that applied to a Psychology department PhD program from the early 1970's to the mid-1980's were required to take the GRE, however, the resulting scores were not part of the selection process, thus circumventing the problem of restriction of range with this population. Predictor data collected from all applicants included undergraduate GPA, GRE-V scores, and GRE-Q scores. Academic performance data in the form of points earned on examinations from several graduate courses (Advanced Statistics, Assessment Methods, and Research Methods in Applied Behavior Analysis) were also collected. An evaluation score calculated by a four-member faculty committee was used as well. The undergraduate GPA and GRE-Total scores (a combination of the verbal and quantitative scores) were used as the predictors in the equation, with the points earned in each of the three graduate courses and the evaluation score from the faculty committee serving as the criterion measurements. The validity coefficients for the GRE-Total scores with each of the four measures of academic performance were significant (ranging from .55 to .70; $p < .00001$ to .0002) and unusually high in comparison to those found in other GRE validation studies.

House and Johnson (1992) conducted a study to evaluate the predictive relationship between the predictor variables of GRE scores, cumulative undergraduate grade point average, and the criterion variable of the length of time (in semesters) from the beginning of students' program of study to the completion of their degree. Records were examined for 291 psychology students who had completed masters degrees within 6 years. Results indicated a statistically significant relationship between undergraduate grade point average and time to degree completion for all students, yet no significant relationship between either the GRE-Q or GRE-V and time to degree completion was observed. When student records were examined within the individual program areas, the results varied. Higher undergraduate grades were associated with fewer semesters needed for degree completion for school psychology students, while higher GRE-Q scores were associated with fewer semesters needed for degree completion for counseling psychology students. In contrast, higher GRE-V scores were associated with more semesters needed for degree completion in experimental/general psychology students. In this last case, the authors noted a possible confound in that experimental/general psychology students may have chosen to complete a master's thesis research project instead of taking comprehensive examinations, thereby prolonging degree completion.

House and Johnson (1993) examined the records of 250 students where five predictor variables were measured: (1) GRE-V, (2) GRE-Q, (3) cumulative undergraduate GPA, (4) grade point average for the last 60 hours of undergraduate study, and (5) grade point average from undergraduate psychology courses. For the dependent measure, students' final degree completion status was used (completed masters degree versus withdrew from college without completing the degree). The analyses show inconsistent results across the different areas of psychology. While the GRE-Q scores as predictors were statistically significant for all students ($p < .05$), the GRE-V scores were the best predictor for professional psychology students, but the worst for the general/experimental students. There was no statistically significant relationship between the criterion variable and any of the other four predictor variables. In this case, results indicate that the GRE plus academic background variables did not predict future degree completion for all students in psychology equally.

Nilsson (1995) conducted a study to determine whether there were any differences in the predictive relationships between the GRE and the GMAT (Graduate Management Admissions Test) when using the GGPA as the criterion variable. Subjects included a random sample of 60 graduate students who had completed at least half of their program of study. Thirty of these individuals were enrolled in business school (having taken the GMAT), and 30 were from various other programs (e.g., English, education, gerontology, etc.), having taken the GRE. In addition to the discovery that the correlation between the GMAT and the GGPA was relatively weaker ($r = .231$), Nilsson found a fairly moderate relationship between the GRE (verbal and quantitative portions only) and GGPA ($r = .449$). Although this was a higher correlation than is commonly reported, a note of caution is necessary, due to the small sample size and lack of control for variables such as subject background or the possibility of test preparation.

Thornell and McCoy (1985) examined the GRE scores and GGPA records of 582 students from four disciplines who had completed their masters degrees. The validity coefficients for GRE-Total ranged from .48 in the Mathematics/Science subsample to .36 in the Fine Arts subsample (all $p < .05$). Similarly, the GRE-V validity coefficients ranged from .42 to .49 (all $p < .05$). Contrasting results reported by House and Johnson (1993), the greatest amount of variability and lowest validity coefficients were found for the GRE-Q, ranging from .22 to .37. The highest correlation for the GRE-Q and GGPA was found for the Mathematics/Science subsample ($p < .05$), and the lowest for the Fine Arts subsample ($p > .05$).

One limitation of Thornell and McCoy (1985) was that students who dropped out of their degree program were not included in the analysis, thereby reducing the amount of correlation resulting from this restriction of range. However, the fact that the GRE was not used as a screening procedure for acceptance of these students enhanced the possibility for reliable correlations (Thornell & McCoy, 1985).

Morrison and Morrison conducted a meta-analytic review of 22 studies (total n = 5,186) published between 1955 and 1992. All studies used the GRE-V and GRE-Q scores as predictor variables and GGPA as the criterion measure of graduate success. The resulting correlation coefficients were .28 for the GRE-V and GGPA (p = n.s.) and .22 for the GRE-Q and GGPA (p = n.s.). These results suggest little predictive value for the GRE.

There is much variability regarding the ability of the GRE to predict success in graduate school, based on the findings of the studies reported here. One thing most authors agree upon is that those in charge of graduate school admissions should use caution when interpreting these scores, and that GRE scores should be used be in combination with other selection criteria.

Preparation for the Graduate Record Examination

Traditional views support the notion that students scoring below a particular cutoff score (e.g., less than 1000 on the combined verbal and quantitative sections of the GRE General Test) do not possess the necessary skills to do well in graduate school (Powers, 1985). Moreover, it is predicted that those same students will not be able to improve their scores enough to achieve an acceptable score on the GRE (Powers, 1985). Therefore, if students have not acquired these verbal and quantitative skills by the time they apply to a graduate program, their options may be severely limited. Despite traditional views, some students seek additional help to improve their verbal and quantitative skills (e.g., preparation courses, published preparation books, practice GRE tests, etc.).

One issue to consider when reviewing the GRE training literature is that of the test-retest reliability of the GRE. Wilson (1988) conducted a study to examine the long term stability of standardized test scores. He found that those repeating the test primarily due to low scores (n = 11,684) did so within two years of their initial testing date, and typically gained between 24 and 32 points on the verbal section, going from 460 (pretest mean) to 488 (posttest mean), and between 26 and 29 points on the quantitative section, going from 489 (pretest mean) to 517 (posttest mean). Test-retest correlation coefficients for the total sample for the verbal and quantitative measures was .86, only somewhat lower than the GRE's internal consistency reliabilities of .92 for the verbal measure and .91 for the quantitative measure. Although the study did not control for confounds such as test-preparation, the authors reported that it is reasonable to expect some improvements in performance on the GRE merely due to retesting and simple regression effects (primarily for short-term test-repeaters), and results reported in the following studies should be interpreted accordingly.

The published literature addressing the issue of test preparation for the GRE is scant. Of those that evaluate specific instructional programs designed to impact GRE scores, only one focuses on the quantitative portion of the examination. Evans (1977) examined the susceptibility of the GRE-Q portion of the test to short-term instruction.

Once a feasibility study demonstrated the interest and commitment of both students and administrators, an exploratory study was designed to identify the specific areas of the GRE-Q that required intensive instruction. The instructional content was derived from analyses of sample GREs administered to the volunteers. A training phase consisted of eight two-hour sessions: (1) testing; (2) test familiarization and anxiety reduction; (3) testing to evaluate the impact of session 2; (4) instruction covering basic number facts, operations with fractions, lowest common multiple, and greatest common divisor; (5) instruction covering averages, ratio and proportion, and percent; (6) instruction covering basic linear algebra and geometry; (7) instruction covering data interpretation; and (8) testing. An operational phase demonstrated that the eight-week program produced an overall positive effect (mean positive intrasubject differences from pretest to posttest ranged from .008 to .140) due to both the instructional program and the test-strategy/anxiety-reduction session, however, there were no statistically significant effects attributed to the mathematical instructional sessions alone. In addition, six of the eleven courses showed positive effects (mean positive intrasubject differences from pretest to posttest ranged from .016 to .191) due to the test-strategy/anxiety-reduction session alone, as did ten of the twelve control groups (mean positive intrasubject differences from pretest to posttest ranged from .003 to .104). Therefore, it is not clear that there were any improvements based on the instructional sessions alone, as those results were not reported independently of the results of the test-strategy/anxiety-reduction session. It may be the case that all of the effects were due to the test-strategy/anxiety-reduction session alone. Interpretation of the results is difficult as the type of pretest and posttest was not indicated beyond that the pretest consisted of 60 items and the posttest consisted of 40 items, and the magnitude of the intrasubject gains was not clear. The difference in number of items from pretest to posttest alone may be responsible for the mean differences reported.

Powers and Swinton (1984) examined whether students taking the GRE were at a greater advantage by engaging in self-instruction, or instructor-guided instruction. They were also interested in the differential susceptibility of the three types of analytical test items to test preparation.

Test-preparation materials were compiled and sent to a random sample of early test-registrants. Materials included (a) one of two sample GRE analytical tests, (b) answers and explanations to the test, and (c) tips for answering analytical questions. A total of 2,400 individuals received some combination of the above materials, and 1,200 of them also received a letter encouraging them to use these materials to prepare for the GRE. Eighteen hundred early registrants served as the control group, with 600 of these individuals receiving the letter of encouragement. Approximately two weeks before the test, all individuals who had received the letter of encouragement also received a postcard reminding them of the test date and again encouraging them to make use of the materials they had previously received. The nonencouraged individuals received a similar postcard, with the exclusion of any encouragement to prepare for the exam.

The authors found that encouragement did not affect the amount of time spent preparing for the test on either the verbal or quantitative component. However, it did appear to have an effect regarding preparation for the analytical component where encouraged candidates spent an average of 3.37 hours preparing and nonencouraged candidates spent an average of 2.80 hours preparing ($p < .05$), although the social significance of this difference is questionable.

Neither test preparation materials nor the encouragement letter had any effect on either the verbal or quantitative scores for the candidates, yet both had a significant effect on the analytical scores. The analytical mean scores were 509.7 for nonencouraged candidates, and 531.8 for encouraged candidates. Score increases were found on two analytical item types: (1) analysis of explanations, and (2) logical diagrams. However, the third item type, analytical reasoning, did not appear to be susceptible to preparation by the materials used in this study.

Though one of the goals of this research was to evaluate self-instruction and instructor-guided instruction, no data were provided for the latter. In the absence of this information, no comparisons can be made.

Powers (1985) examined the effects of coaching on GRE performance. Subjects included 5,107 test-takers from the June 1980 administration of the GRE. Most of these individuals received materials to help them prepare for the analytical portion of the examination, and were later surveyed to determine the methods by which they prepared for all portions of the test. Of the candidates surveyed regarding their participation in test preparation activities or lack of, only about 3% of the total sample reported attending a test preparation program, in contrast to approximately 90% reporting having prepared by reading the *GRE Information Bulletin*, or taking the sample test included in the *Bulletin* (78%). The number of hours spent in a coaching program varied substantially, with means of 8.0 hours for the verbal portion, 9.4 for the quantitative, and 8.0 for the analytical, with a range of total hours spent preparing for all sections of 1 to 45 hours. Those students who were coached had lower GRE scores on the average than those who were not coached (verbal: -15.4, quantitative: -4.7, analytical: -3.1). Mean scores for the coached and uncoached samples were 474 and 492 on the verbal component, 475 and 505 for the quantitative component, and 526 and 540 for the analytical component, respectively. Only the scores on the analytical portion of the examination were related significantly to the length of time spent in the coaching program. For the quantitative portion, the type of coaching program contributed significantly to the prediction of coaching effects ($p < .001$), but not for the verbal or analytical sections.

Powers notes that the scores of the coached individuals were lower than those of uncoached candidates due to potential effects of other variables such as the coached group being a self-selected sample. In addition, it was concluded that GRE performance appears to show little susceptibility to the type of coaching described in this paper. However, in the absence of any reported differences in pretest and posttest scores, it is impossible to determine any effects of the various coaching programs.

Swinton and Powers (1983) conducted a study to assess the effects of teaching testing-strategies and providing practice for test-familiarization on the analytical portion of the GRE. The nonrandomized sample of students attended a course for a total of 7 hours in which two versions of the analytical portion of the GRE were used in conjunction with the instruction on testing-strategies.

The differences in analytical performance of the treatment group (those taking the course) vs. control group (all other students taking the GRE on the same day) were statistically significant. The mean score on the analytical portion of the GRE was 591.5 for the treatment group ($n = 25$) to 530.7 for the control group ($n = 415$). The improvements were attributed to the performance on two types of analytical questions: (1) analysis of explanations (treatment group mean = 28.6; control group mean = 24.2), and (2) logical diagrams (treatment group mean = 12.1; control group mean = 10.7). No differences were found on the verbal and quantitative portions of the examination. The authors concluded that the analytical training was responsible for the higher scores.

Opposing traditional theories, the behavior analytic view supports the notion that students can improve their performance on the GRE through intensive, extensive, structured practice of verbal and quantitative skills (Miller, Goodyear-Orwat, and Malott, in press). In 1994, students participating in one of three GRE-preparation courses achieved significant improvements both overall (M=96, p<.05), and in the separate verbal and quantitative portions of the examination from pretest to posttest (verbal portion: M=39.5, p<.05; quantitative portion: M=56.5, p<.05). Retired versions of actual GREs served as the pretests and posttests.

These courses lasted from 5.5 to 7.5 weeks, totaling 66 to 140 hours of study. Students were required to attend the course a minimum of 92% of the time in order to earn a $50 rebate at the end of the course. The format of the course was self-paced and self-instructional. Using several books and software programs (e.g., Barron's How to Prepare for the GRE, 1993-1994; The Princeton Review: Cracking the GRE, 1992; Think Fast, 1992) students spent four hours each day, five days a week, for seven weeks, preparing for the examination. The instructor was available to answer questions and assist the students in planning their studying activities.

Teaching Remedial Mathematics

Gickling, Shane, and Croskery (1989) explored a method for improving the mathematics skills of low-achieving high school students through curriculum-based assessment (CBA) -- matching what is being taught with what is being tested, which is a method for steering the instructional process to provide optimum learning conditions. CBA is further defined by the authors as a system for determining the instructional needs of a student based upon the student's on-going performance within existing course content to deliver instruction as effectively and efficiently as possible.

In this study, Gickling et al. compared CBA procedures with traditional teaching methods to teach mathematics. The instructor administering the CBA essentially followed these six procedures: (1) introduce the skill being presented in the current lesson, (2) comment on the subject's performance on the previous lesson, (3) recap a previously learned skill that was directly relevant to the current lesson, (4) review a mistake on the previous lesson and model the proper problem solving procedure next to the mistake, (5) provide guided practice by prompting the correct procedures and response on a number of problems, and (6) allow the subject to demonstrate skill mastery by working a series of problems without assistance. The traditional teaching method involved the regular presentation of concepts in lecture format and provision of mathematics problems for practice. The drills that were developed consisted of a ratio of 70-85% known items (i.e., items with which students had had previous practice) and no more than 15-30% challenge items (i.e., items with which students had not had previous practice).

After the nine-week intervention period, the second administration of the standardized tests resulted in significant gains for both the treatment group and the control group ($p < .001$ and $p < .01$, respectively), yet there were no significant differences between groups. It should be noted, however, that while only 47% of the control group subjects were still attending the sessions at the end of the nine week intervention period, 67% of the subjects in the treatment group were still participating. Thus, the CBA style of teaching mathematics may have some retention value, in addition to the fact that there may have been between group differences had the attrition of the control group been lower, as these data were eliminated from the analysis.

Kelly, Gersten, and Carnine (1990) conducted a study evaluating two curriculum approaches to teaching mathematics in high-school remedial classes. While both conditions incorporated instructor-guided practice prior to independent seatwork, uninterrupted successful practice before going on to a new skill, daily feedback on mathematics problems and regular review of newly acquired concepts, the instructional design curriculum also incorporated the following components: (a) systematic practice in discriminating among related problem types (Darch, et al., 1984; Englert, 1984); (b) separation of confusing elements and terminology (Carnine, 1980a); and (c) use of a wide range of examples to illustrate each concept (Carnine, 1980b).

Performance on the subtest differed significantly between the two groups ($p < .01$). The mean pretest scores were around 40% for both groups, while the posttest scores were 96% and 82% for the instructional design and treatment group, respectively. The authors concluded that, while both instructional curricula produced significant effects, the significantly higher scores ($p < .005$) of the instructional design group indicate that "providing a wider range of examples, clearer step-by-step strategies, and discrimination practice can augment the effectiveness of any mathematics curriculum" (p. 28).

Carroll (1994) found that providing worked examples (mathematical problems with the answers provided along with steps for finding the solutions) for solving algebraic expressions was beneficial. Subjects were administered a 20-item test, assessing skills in arithmetic and basic algebra, which served as the pretest and posttest. Based on their scores, students were then paired and randomly assigned to either a worked example or a conventional practice group. Those using the worked examples (each worksheet contained 12 worked examples, each one followed by one similar practice problem) outperformed those who did not use them. Moreover, the worked examples group made fewer errors than the conventional practice group (mean errors for worked example group = 1.25; mean errors for conventional practice group = 4.40; $p < .05$).

Bottge and Hasselbring (1993) developed an intervention to teach remedial mathematics students to solve fraction problems in real-life situations. Subjects included 36 9th-grade students in two remedial mathematics classes. The materials were designed to teach adding and subtracting fractions in relation to money and linear measurement. There were five dependent variables: (1) an 18-item fractions-computation test (addition and subtraction); (2) an 18-item word-problem test involving single-step and multi-step word problems requiring addition and subtraction of fractions; (3) an 8-min video, *Bart's Pet Project*, requiring a solution based on calculations of numbers provided within the video; and (4) two transfer tasks, one of which was a text-based problem, and the other a video-based contextualized problem.

The fractions-computation test was administered before and after an instructional videodisk, Mastering Fractions (Systems Impact, 1985). The instructional disk consisted of 35 lessons (including mastery tests, quizzes, reviews, and remedial exercises), from which particular lessons were selected based on error-analyses of the fractions-computation pretest to form a five-day instructional sequence. Based on performance on the fractions-computation posttest, students were first ranked and then randomly assigned to either the contextualized-problem or word-problem group. Before further instruction, students then took both the word-problem test and the video-problem test. Instruction and practice problems in the contextualized-problem group were presented to the students in a familiar context, while instruction and practice was presented to the word-problem students in largely unrelated contexts, although the basic computations were identical.

The video-disk instruction resulted in significant gains in performance from pretest to posttest on the fractions computation test ($p < .01$), and nearly identical scores on the posttest to those of the remedial-mathematics students' grade-level peers in prealgebra. However, performance on the word-problem test showed significantly greater scores for the prealgebra students ($M=23.75$) than the remedial students ($M=17.16$) ($p < .001$). Following the instruction on word-problems within the word-problem and contextualized-problem groups, performance on the word-problem test and video-problem test was greater for the contextualized-problem group ($p < .01$). as was performance on both of the transfer tasks ($p < .05$). These result suggest that although remedial students performed at the level of prealgebra students in basic computations, the skills did not transfer to the more complex skill of solving word-problems. Thus, additional direct instruction was necessary in order to improve the more complex skills, and when presented in context, even greater gains were achieved.

Nunez-Wormack, Astone, and Smodlaka (1992) used a comprehensive prefreshman summer program model to achieve statistically significant results with incoming college freshmen in 1988 (n=112), 1989 (n=105), and 1990 (n=267). The program focused on improving basic skills in reading, writing, and mathematics, involving a total of 45-60 hours of intensive instruction. Pretest to posttest scores on a standardized mathematics examination showed significant improvements for 484 students during a three-year period while this program was evaluated (1988: pretest mean = 19.1, posttest mean = 29; 1989: pretest mean = 17.8, posttest mean = 31.1; 1990: pretest mean = 18.7, posttest mean = 28.8; $p < .000$ for all three years). Explanations of materials and style of instruction were not provided beyond indicating that teachers were responsible for selecting their materials from those used in the standard mathematics courses at the university.

Cadet and Heerman (1990) achieved significant gains in mathematics performance in a college laboratory, as an alternative to the classroom methods previously described. The dependent measures were pretest and posttest performance on the Preprofessional Skills Test (Educational Testing Services, 1986). An instructor reviewed pretests and diagnosed special needs through an analysis and classification of practice test errors. Following the diagnosis, a minimum of 15 hours of instruction was provided for student in skill areas where any deficiency was apparent. Upon completion of the instruction and testing strategy phase, the official administration of the Preprofessional Skills Test (PPST) served as the posttest for each student. The pretest-posttest gains were significant ($p < .001$).

The authors noted two components which may have contributed to the success of this laboratory. First, that the instructor was a competent, paid faculty mathematics tutor and second, the self-selected nature of this sample. These students were motivated to improve their mathematics skills as they wanted to be admitted to a teacher education program. This laboratory may not have had the same success if those using it were not similarly motivated.

Chang (1977) assessed the effectiveness of a small-group instructional method as compared to a more traditional lecture-demonstration method in teaching remedial mathematics. The dependent variables were two types of pretests and posttests, arithmetic achievement at the beginning and end of the course, and elementary algebra achievement at the beginning of the 3rd week and at the end of the course.

The small-group method of instruction incorporated the following steps: (a) the students in one section were divided into groups of three or four, with the pretest high-achievers evenly distributed; (b) the instructor lectured for the first five to ten minutes of the class period to introduce new information, with the remaining thirty to forty minutes spent in small-group activities; (c) the last five to ten minutes were reserved for class discussion; and (d) the instructor served mainly as a consultant in the event that a group needed help.

The lecture-demonstration method of instruction consisted of the following steps: (a) the instructor lectured for thirty to thirty-five minutes during each course to present new material, (b) the last fifteen to twenty minutes of each period were reserved for class discussion, and (c) the instructor primarily presented new information and helped individuals during the class discussion.

The small-group method was superior to the lecture-demonstration method on both tests, but significantly superior on only the elementary algebra test (small group method: arithmetic pretest mean = 13.71, posttest mean = 22.14; $p < .05$; elementary algebra pretest mean = 10, posttest mean = 18.14; $p < .05$; lecture demonstration method: arithmetic pretest mean = 12.64, posttest mean = 17.21; $p < .05$; elementary algebra pretest mean = 9.21, posttest mean = 11.86; $p > .05$).

Computer-Based Instruction

As an alternative to traditional paper-and-pencil methods of teaching both initial and remedial mathematics, computer-based or computer-assisted instruction has received attention as an effective way to individualize instruction. Dalton and Hannifin (1988) examined the effects of mastery-based computer-assisted and mastery-based traditional methods of teaching on the performance of students learning simple algebraic computations. Mastery learning is essentially a method involving the teaching of ordered skills through a systematic cycle of teaching, testing, and remediating to criterion performance levels (Block, 1979; Slavin, 1987a).

One hundred and seventeen subjects were randomly assigned to one of five groups focusing on computing the area of a circle: (1) traditional instruction with traditional remediation, (2) traditional instruction with computer remediation, (3) computer instruction with traditional remediation, (4) computer instruction with computer remediation, and (5) control group. The first four groups included mastery criteria, while the control group used traditional methods of instruction, with no remediation, and no mastery criteria.

The traditional instruction and remediation were presented by an instructor, while the computer instruction and remediation involved the instructor only as a supervisor. All four experimental groups were required to achieve levels of mastery before completing a multiple-choice posttest. The average performance on this test for the mastery groups (84.87) was significantly greater than that of the non-mastery control group (64.78) ($p < .0005$). There was a significant interaction between initial instruction and remediation strategy ($p < .05$). Student performance was higher when the method of instruction was varied between traditional teacher-based and computer-assisted (i.e., initial teacher-based instruction and computer-assisted remediation, or initial computer-assisted instruction and teacher-based remediation).

Through a series of four studies, Ross, McCormick, Krisak, and Anand (1985) evaluated the effects of personalizing the context of mathematical instructional materials as the groundwork for the development of a personalized computer-assisted instruction model. The purpose of these studies was to determine whether it is beneficial to provide such individualized adaptation of instructional materials to student background.

The first and second studies utilized three forms of a self-paced instructional unit on probability. Each of the three forms contained instruction and examples embedded within a different context: (1) education, (2) medical, and (3) abstract. Participants in studies one and two were education majors and nurses, respectively. Subjects were randomly assigned to one of the three forms of instruction, upon completion of which they took a 20-item posttest. Performance results, although not provided, were noted as demonstrating support for the adaptive method of instruction, with education majors performing better on the education items of the posttest, and nursing majors performing better on the medical portion of the posttest.

Study 3 examined the same materials under regular course conditions, in an effort to provide evidence of external validity, for nursing students. Significant treatment effects were present for education-context items ($p < .01$); medical-context items ($p < .05$); and total score of the posttest ($p < .05$). On education items, the adaptive (medical) group outperformed both the nonadaptive (education) and the abstract (using general terms such as events, trials, and items) groups. On medical-context items as well as total score, the adaptive group performed better than the abstract group.

Study 4 examined whether individual choice of context for instruction would affect performance. Eighty nursing students were randomly assigned to one of four groups: (1) learner adaptive, where the individuals received the context they favored from a list of options; (2) standard-adaptive, where all students received the medical context; (3) standard-nonadaptive, where all students received the abstract context; and (4) learner-nonadaptive, where all students received the context that they least preferred from a list of options.

Posttest results showed that adaptive contexts (mean = 59%) were superior to nonadaptive contexts (mean = 42.5%). The results of the previous studies were used to support the development of a CAI model with the following goals: (a) personalize context for each individual user; (b) create contexts which cover many different areas and backgrounds (e.g., sports, hobbies, school); and (c) automate the tasks of presentation and evaluation. Initial analysis of the available data for approximately ten subjects per condition indicate significant differences in performance between students using the personalized, concrete (thematically appropriate, but fictitious names and events), and the abstract programs. They found that: (a) students performed better on conventional word problems when using the personalized system over the abstract system ($p < .05$), and (b) students performed better on number problems, attitude scores, and memory of rule procedures when using the personalized system over both the abstract and concrete systems ($p < .01$, $p < .05$, and $p < .01$, respectively).

Gourgey (1987) assessed whether the method of administration of computer-assisted instruction (CAI) is critical to its success in teaching mathematics. The particular format of this CAI is drill and practice, where the computer presents a problem, the student enters an answer, and the computer immediately provides feedback.

All subjects worked with the drill and practice computer program (Computer Curriculum Corporation) approximately 10 minutes each day, for a total of 50 minutes each week. Three variations on instructional methods were used:

1. CAI plus coordinated instruction , where the teacher lectured over mathematical topics for 20 minutes, directly linking the topics to the CAI topics of the day.

2. CAI plus reinforcement, where students had a different math teacher and computer lab teacher. The classroom teacher lectured over math topics for 20 minutes, then students attended a computer lab for the remaining 10 minutes where the computer lab instructor provided reinforcers contingent upon good performance. The two instructors did not communicate to coordinate the lesson plans and CAI.

3. CAI without reinforcement, where once again, the two instructors did not communicate to coordinate lesson plans with the CAI.

All three groups showed improvement on mean performance from pretest to posttest on the computational portion of the test (CAI/coordinated: pretest = 38.71, posttest = 55.57; CAI/feedback: pretest = 39.47, posttest = 49.51; CAI/alone: pretest = 37.13, posttest = 46.69) and on the concepts portion of the test (CAI/coordinated: pretest = 26.62, posttest = 41.85; CAI/feedback: pretest = 28.40, posttest = 35.40; CAI/alone: pretest = 25.44, posttest = 31.00). Students in the CAI plus coordinated instruction group performed significantly higher on the computation portion of the test than did the other two groups combined ($p < .05$) as they also did on the concepts portion of the test when compared to the two groups separately: CAI plus reinforcement ($p < .01$), and CAI alone ($p < .01$). Therefore, the most effective method of instruction was one that combined formal classroom instruction with drill and practice CAI. Furthermore, the method of administration of CAI did affect student performance in this case.

Fluency Instruction

Fluency is a combination of accuracy (or quality) and speed. The notion of fluency comes from the literature on learning, particularly the work done by precision teachers. They purport that building fluency of basic "tool" skills fosters higher order learning, improved memory of concepts, greater endurance of performance and greater application of concepts (Parsons, 1984). Tool skills are the key component skills for a particular task (e.g., one tool skill for long division is the ability to write the numbers 0 to 9) (Johnson & Layng, 1992).

According to precision teachers, fluency ensures that students will be able to perform easily in the presence of distraction, will be able to retain newly-acquired skills and knowledge, and will be able to apply what they've learned to acquire new skills or to real-life situations (Binder, 1988). In addition, the definition of fluency requires the skill to be available to the selecting environment as a behavior that can be readily linked or combined with other behaviors, thereby allowing students to perform complex tasks and solve complex problems. For example, a teacher may be teaching her students the spelling rule of doubling the final consonant before adding an ending that begins with a vowel. Often, instructors will stop when the student can perform this task accurately, regardless of the number of times they can perform the task during a particular interval. The fluency method goes beyond training for accuracy. If the student practices applying this spelling rule repeatedly, with goals made up of both accuracy and frequency, and can build this skill to almost the same level of fluency as in writing his or her name (assuming this is fluent), he or she will be much more likely to apply this skill in the future under appropriate circumstances (Johnson & Layng, 1992). The problem that is presented may not be the problem to solve. In other words, it may instead be indicative of a deficit in one or more tool skills of which the particular problem is comprised. For example, Haughton (1972) found that when students lack proficiency with basic arithmetic computation (e.g., 50-70 problems per minute), they usually experience difficulty learning long division, algebra, and other advanced math skills. This generative aspect of fluency is one which has great applicability when designing the sequence of both teacher-based instruction and materials.

Fluency training is one component of effective instruction, and is applicable in many settings beyond the classroom. Research from several fields demonstrates the importance of using timed assessment procedures to define mastery, including: verbal behavior, human factors engineering, human information processing theory, perceptual-motor learning, and applied behavior analysis. The present research focused on the role of fluency training as applied to instructional design.

Some sequences of coaching, or instructional training, for the Graduate Record Examination are widely available (e.g., Kaplan courses), however, the addition of the fluency training to focus on speed as well as accuracy is novel. This line of research is important for two reasons. First, there is a relatively small body of literature on the topic of fluency. Although there are a number of people using these techniques and focusing on fluency training, published research is limited. And second, although improvements have been achieved in students' GRE scores in past sessions of this preparation course, the goal was to explore the extent to which even greater improvements could be obtained, maintaining continuous quality improvement of the current methods of instruction.

Attempts were made to (a) train specific tool skills necessary for performance on the quantitative portion of the GRE, (b) identify which materials are helpful in training these skills, and (c) design effective instructional materials with which to apply the fluency training. This study is a continuation of previous research aimed at identifying the most effective way of preparing students to take the GRE. Similar courses were conducted in 1993 and 1994. Although the course materials and structure are parallel to those of the previous sessions, this sequence of GRE-preparation courses focused primarily on the quantitative portion of the examination; it was designed to discover whether intensive practice of quantitative skills, applying both speed and accuracy goals, would substantially improve students' performance on the GRE.

CHAPTER II

SPRING, 1995 COURSE

Introduction

This study was conducted throughout the spring, summer and fall semesters of 1995 at Western Michigan University within a GRE-preparation course offered during each of these semesters. As each course differed somewhat from the preceding course, the spring semester course will be described in its entirety, with each subsequent course described in terms of its variations from the preceding one. The materials used to prepare for both the verbal and quantitative portions of the examination during the spring semester will also be described in detail, and the addition, modification, or elimination of materials for subsequent courses will follow.

Additional research studies were also conducted to analyze the effectiveness of the fluency drills used within the courses. These are described following the descriptions of the preparation courses.

Methods

Subjects, Setting, and Structure

The GRE-preparation course offered during the university's spring semester met for a total of 140 hours, 8:00am to 12:00pm on Monday through Friday for seven weeks. The course was sponsored jointly by the Psychology department and the Office of Conferences and Institutes at Western Michigan University. It took place in two classrooms on campus which were equipped with tables, desks, and chairs. One of the rooms also contained 20 Zenith 286 computers. Six students enrolled in this course and were required to pay a fee of $385, which included the cost of all materials.

Students were recruited in two ways: First, an advertisement was placed in the university newspaper, announcing the course schedule and showing a graph which identified the results in terms of pretest to posttest improvement of students completing the course in 1993. Second, the experimenter visited junior and senior level psychology courses to distribute informational flyers, describe the format and content of the course and to answer questions. The flyers described the course in terms of the schedule, content, goals, and registration information (Appendix A). These were collected at the end of the class period from those students who had completed the student information portion of the form (name, phone number, and semester preference for taking the course). These students were then contacted in order to begin the registration process.

On the first day of the course, all students signed an informed consent form (Appendix B) and completed a retired version of a GRE (i.e., an actual GRE which was used in the past and is now published by the Educational Testing Services). Students were randomly assigned to one of two versions of the examination (GR92-1 or GR92-2). As universities are most likely to be interested in the verbal and quantitative portions of the GRE, only those portions were included, eliminating the analytical portion of the general test. The test consisted of four 30 min sections, two verbal and two quantitative. Upon completion, students were introduced to the format and policies of the course. Each received a syllabus containing the anticipated course schedule (Appendix C). The format was explained as an intensive, structured, study system designed to enable students to devote the necessary time to improve their verbal and quantitative skills, hence maximizing their performance on the GRE. To encourage steady attendance, all students who completed the course with a minimum of 92% participation were eligible for a $75 rebate. In the event that a student had to miss all or part of a session, performance contracting for time outside of class was available as an option in order to retain eligibility for the rebate. However, this option was limited to planned absences (i.e., students had to inform the instructor before the session began if they were going to be absent). If students were more than five minutes late, they were required to make up the time in order to remain eligible for the rebate.

Students were randomly assigned to one of two groups for the duration of the course. Group 1 focused on verbal training during the first half of the semester and quantitative training during the second half of the semester. Group 2 participated in the same training sequences in the opposite order. Students worked at their own pace to complete the reading and practice problems within the books provided for both the verbal and quantitative skills. For the first week, students spent the first hour of each session reading a portion of the pages in Barron's How to Prepare for the Graduate Record Examination (Brownstein, Weiner, Green, & Hilbert, 1994) which introduced them to different strategies to use while completing either the verbal or quantitative portion of the GRE. The remaining three hours for the students focusing on the verbal materials were spent using Think Fast (Parsons, 1992) to learn the vocabulary words. The remaining three hours for the students focusing on the quantitative materials were spent reading and completing problems in Mathworks (Frieder, 1982) and completing fluency drills. After the first week, all four hours were devoted to improving verbal and quantitative skills with Think Fast, Mathworks, and fluency drills. Each student typically took a break for 5-10 min each hour.

On the last day of the semester, each student took a different retired version of the GRE as his/her posttest (i.e., if a student took version GR92-1 of the GRE as her pretest, she would then take version GR92-2 as her posttest). Students then completed an evaluation of the course in terms of the format, materials, and perceived benefit

(Appendix D). The evaluations are summarized by course following the results of the fall GRE-preparation course.

Materials

Verbal Training

Barron's contains 28 pages of strategic information regarding the verbal portion of the examination, along with a list of 3500 words potentially found on the GRE. In addition, the book contains a list of the 300 most frequently found words, out of the 3500 words on the original list. These 300 words were entered into Think Fast through the editing function of the software. This enabled students to test themselves on the definitions of these words. Each student received a diskette containing Think Fast, and after completing a short tutorial, students used the program as a computerized flashcard system. The words are divided into six units of 50 words each. A unit is referred to as a "deck". Once a deck is selected by the student, the computer randomly presents the words, one at a time, on the screen. If the word was one with which the student was already familiar, he/she pressed the "enter" key on the keyboard to have the definition presented for review, or pressed the enter key twice to skip the definition and move on to the next word. If the definition was not known, he/she studied the definition and learned it by saying it to himself/herself. This process of presenting the words and definitions was repeated until the student knew all 50 words in the deck. Students could either keep all 50 words in the deck so that they would review each one on each cycle through the deck, or they had the option of "dropping" a definition out of the rotation once they were confident they knew the meaning of the word. Approximately 25% of the students reported using the drop technique, and then adding the words back in at the end for one final review before moving on to the next deck. The nature of this task relied on self-evaluation to the extent that the student "knew" each definition. Students received a form listing all of the decks in the program, to make notes and mark the date of completion as a method for tracking their progress. These forms were collected at the end of each session and stored in the students' individual folders.

Quantitative Training

Students prepared for the quantitative portion of the GRE by focusing on three areas: (1) testing strategies provided by Barron's (2) review and practice provided by Mathworks (Frieder, 1982) , and (3) quantitative drills based on material from Mathworks (Frieder, 1982), and generated by Exam-in-a Can (International Publishing Services, 1995). As in the verbal training sequence, the first hour of each session for the first week was spent learning and reviewing test-taking strategies in Barron's (Brownstein et al., 1994), with the remaining three hours spent reading Mathworks (Frieder, 1982) and completing the drills. Once the test-taking strategy pages in Barron's were completed, students spent the entire four hours reviewing math skills from Mathworks and completing the fluency drills.

After reviewing the content of several GRE-preparation books, Mathworks (Frieder, 1982) was selected by the experimenter to guide the content of the spring course, as it was the most comprehensive. Using Exam-in-a-Can (International Publishing Services, 1995), a set of mathematical drills was developed as a supplement to the first portion of Mathworks which focused on basic arithmetic. This software program is essentially a "generating engine", that produces mathematical drills covering a wide range of skills from basic mathematical concepts through geometry. The instructor was able to identify which objectives to include in a particular drill, choose the format of each question (i.e., multiple-choice or free response), and print any number of versions of the same drill (e.g., 20 different forms of the same basic addition test, with each drill differing only regarding the particular numbers inserted in each problem) (Appendix E).

Four drills, each consisting of four components, were created: (1) Basic math: addition, subtraction, multiplication, and division; (2) Fractions: addition, subtraction, multiplication, and division; (3) Percentages: addition, subtraction, multiplication, and division; and (4) Decimals: addition, subtraction, multiplication. Each drill was approximately 6 pages long, and each page contained approximately 20-25 problems, for a total of approximately 130 items per test.

Students were instructed to first read the relevant section of Mathworks (e.g., basic arithmetic) which was used as a review and instruction tool. When finished with a review section, students completed a drill covering the basic arithmetic skills. Using a stopwatch, they timed their progress throughout each drill. Each page of each of the four quantitative drills had a fluency aim (i.e., a goal consisting of criteria for both accuracy and speed). Based on a method recommended for developing fluency aims by Heward and Miller (1992), the goal was derived from the performance of an exemplary student (one who had achieved a score of 750 out of a possible 800 points on the quantitative portion of the GRE, placing her at the 90th percentile of all candidates taking the GRE in the spring of 1992). Each drill had a goal of 100% accuracy, and a particular speed goal (e.g., the second page of the basic skills addition drill had a goal of 100% accuracy, to be completed in 1:29). The objective was for each student to work as quickly and as accurately as possible while working on each individual drill, yet move at his/her own pace throughout the sequence of drills along with the corresponding sections of Mathworks.

Students were responsible for recording their progress throughout the fluency drill sequence. Upon arrival at class, students selected their personal file of quantitative drill records. Once determining where they were in the sequence, they selected the appropriate drill, a stopwatch, and blank answer forms. When prepared (e.g., after reviewing particular sections in the Mathworks text, and/or asking questions), students began the drills. This involved starting the stopwatch, working through the drill as quickly and as accurately as possible using scrap paper to analyze the problems, recording the answers on the answer form, and stopping the stop watch. Upon completion of a drill, students selected the corresponding answer sheet, corrected their answers, and returned the drill and answer sheet to the file folder. The instructor then recorded the number of correct items, and the time it took to complete the drill on the student's data collection form (Appendix F). In order to advance to the next section of Mathworks and the next corresponding drill, two criteria must be met. First, the student must complete the drill with 100% accuracy, and second, he/she must complete the drill within the pre-established speed criterion. If a student achieved the goals for all but 2 pages of a drill, he/she was permitted to focus exclusively on those 2 pages until the goals were met. If the student did not achieve either the accuracy criterion, the speed criterion, or both, he/she would select another version of the same drill (e.g., form 3 of Basic Math), noting which forms of the drill he/she had previously completed, and repeat the process. This cycle continued until the student met the criteria. Once the criteria for an individual drill had been met students selected a version of the next drill in the sequence and repeated the procedure.

Periodic reliability checks were conducted to ensure correct evaluation of progress by students. During a reliability check, the instructor (a) timed the completion of the drill concurrently with the student, (b) observed the completion of the drill, and (c) re-graded the student's answer form.

Results

During the spring semester, five of the six enrolled students completed the course. Of those five, only one received the $75 rebate for a minimum of 92% participation. The following analyses are limited to those who completed the course. In all cases, the mean scores are reported as the means and medians were essentially the same.

The mean GRE-T (combined verbal and quantitative) pretest score was 824 and the mean posttest score was 1016 (Table 1) for a overall improvement of 192 points (M=192, SD=76.3), $t(5)=5.63$, $p < .01$ (Figure 1). The scores ranged from 740 to 920 for the pretest and from 880 to 1160 for the posttest. The mean pretest and posttest scores for the verbal component were 350 and 424 respectively (Table 1), for a mean improvement of 74 points (M=74, SD=55), $t(5)=3.01$, $p < .05$ (Figure 1). The verbal pretest scores ranged from 290 to 400, and the posttest scores ranged from 360 to 500. The mean pretest and posttest scores for the quantitative component were 474 and 592 respectively (Table 1), for a mean improvement of 118 points (M=118, SD=43.2), $t(5)=6.10$, $p < .01$ (Figure 1). Scores on the quantitative pretest ranged from 370 to 630 and posttest scores ranged from 520 to 800.

Two of the five students completing the course took the October administration of the GRE. The mean improvement on the verbal portion of the test was 60 points and the mean improvement on the quantitative portion was 90 points, for a GRE-Total mean improvement of 150 points (Figure 2). Overall pretest scores were 740 and 810 ($\underline{M}$=775), and overall actual GRE scores were 920 and 930 ($\underline{M}$=925).

Table 1

Mean Pretest and Posttest Scores for Spring Course

	Pretest	Posttest	Improvement	N
GRE-V	350	424	**74***	5
GRE-Q	474	592	**118****	5
GRE-T	824	1,016	**192****	5

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

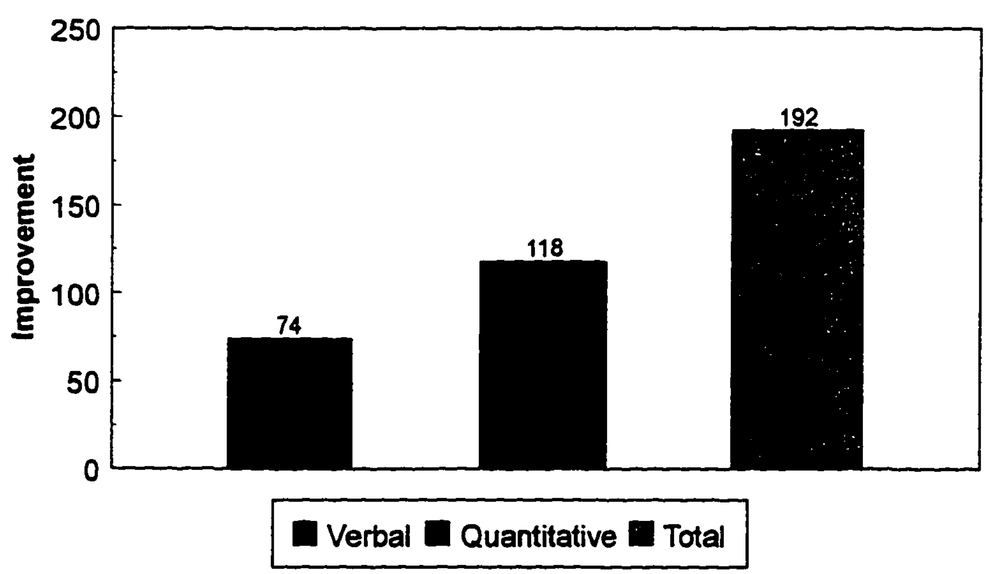


Figure 1. Mean Verbal, Quantitative, and Total Improvement From Pretest to Posttest for All Students Enrolled in the Spring Course.

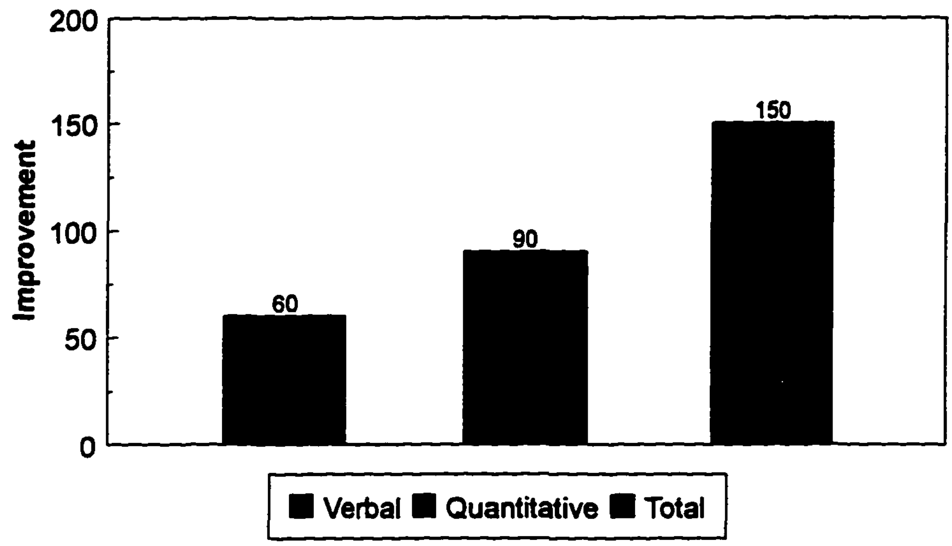


Figure 2. Mean Verbal, Quantitative, and Total Improvement From Pretest to Actual GRE for Students Enrolled in the Spring Course.

CHAPTER III

SUMMER, 1995 COURSE

Introduction

This course was essentially a direct replication of the spring course, with the exception of added structure as noted below. The same fluency drills were used again in an effort to reproduce the significant improvements on the quantitative portion of the GRE from pretest to posttest.

Methods

Subjects, Setting, and Structure

Ten students enrolled in the summer preparation course. Each student received a schedule to follow that provided a list of tasks (e.g., practice problems and reading materials) to complete in a calendar format. Although the schedule was created with specific dates, it was used as a rough guideline, as these courses are primarily self-paced. This component was added to increase the amount of structure with the goal of ensuring all students covered all materials by the end of the course. The same materials were used in the summer preparation course for both the verbal and quantitative preparation sequences.

Results

During the summer semester, seven of the enrolled students completed the course. Of those seven, four received the $75 rebate for a minimum of 92% participation. The results reported below are limited to those who completed the course.

The mean GRE-T (combined verbal and quantitative) pretest score was 867 and the mean posttest score was 983 (Table 2) for an overall improvement of 116 points (M=116, SD=65), $t(7)=4.71$, $p < .05$ (Figure 3). + The scores ranged from 710 to 1010 for the pretest and 770 to 1060 for the posttest. The mean pretest and posttest scores for the verbal component were 420 and 467 respectively (Table 2), for a mean improvement of 47 points (M=47, SD=46), $t(7)=2.71$, $p < .05$ (Figure 3). The verbal pretest scores ranged from 340 to 510, and the posttest scores ranged from 350 to 640. The mean pretest and posttest scores for the quantitative component were 447 and 516 respectively (Table 2), for a mean improvement of 69 points (M=69, SD=54.6), $t(7)=3.32$, $p < .05$ (Figure 3). Scores on the quantitative pretest ranged from 370 to 540 and posttest scores ranged from 400 to 580.

Four of the seven students completing the course took the October administration of the GRE. The mean improvement on the verbal portion of the test for these students was 76 points, and the mean improvement for the quantitative component was 2, for a GRE-Total mean improvement of 78 points (Figure 4).

Overall pretest scores ranged from 900 to 1010 (M = 987) and overall actual GRE scores ranged from 980 to 1060 (M = 1035).

Table 2

Mean Pretest and Posttest Scores for Summer Course

	Pretest	Posttest	Improvement	N
GRE-V	420	467	**47***	7
GRE-Q	447	516	**69***	7
GRE-T	867	983	**116***	7

* $p < .05$

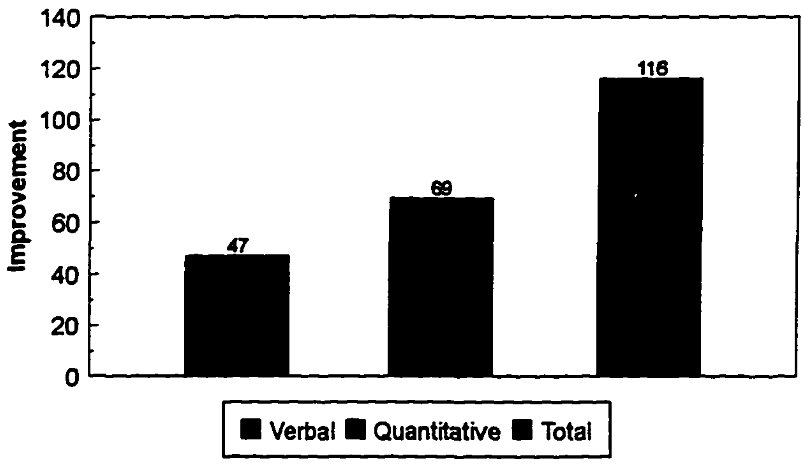


Figure 3. Mean Verbal, Quantitative, and Total Improvement From Pretest to Posttest for All Students Enrolled in the Summer Course.

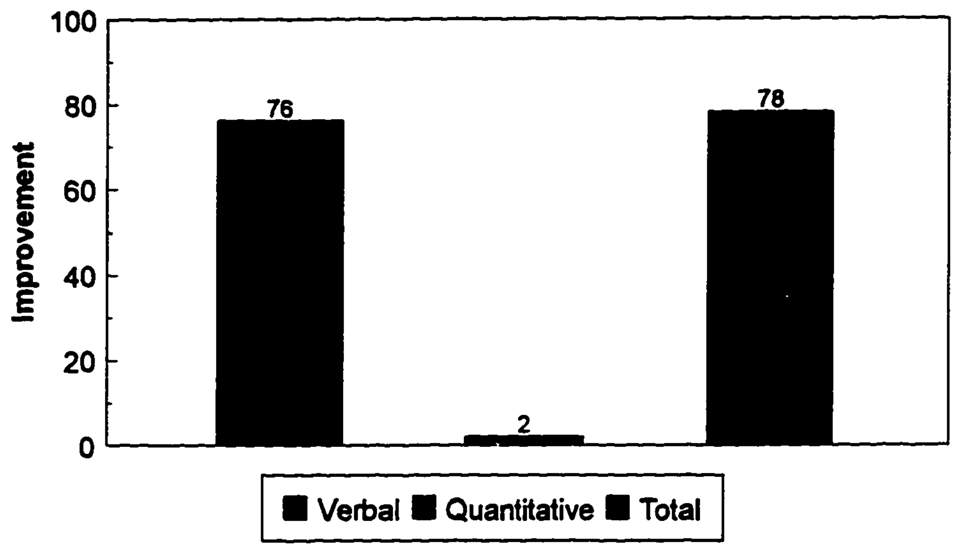


Figure 4. Mean Verbal, Quantitative, and Total Improvement From Pretest to Actual GRE for Students Enrolled in the Summer Course.

CHAPTER IV

FALL, 1995 COURSE

Introduction

The students in the first two courses using the basic math fluency drills showed improvements on the quantitative portion of the GRE. As the students in the spring and summer courses focusing only on basic math skills improved their scores an average of 90 points from pretest to posttest, the fluency drill sequence was extended to cover all skills represented on the GRE (i.e., algebra and geometry in addition to basic math) in an attempt to achieve even greater improvements. However, given the limited amount of time for students to achieve fluency on the entire range of skills, the speed criterion was lowered to that of 90% of the exemplar's fluency level, although students were still required to meet the 100% accuracy goal. In addition to the modification of the criteria, the drills were separated by skills and subskills more concisely, as described in the following methods section.

It is an empirical question as to the proper balance of the amount of basic skill training that might produce generativity to the advanced skills and the amount of direct training on the advanced skills. Therefore, in this course, the amount of training on the basic skills was decreased and the amount of training on the advanced skills was increased.

Methods

Subjects, Setting, and Structure

During the fall semester, eight students enrolled in the course. For all eight students the first 3.5 weeks of the semester were dedicated to the verbal training, and the second 3.5 weeks were dedicated to quantitative training. Students met from 6:00pm until 10:00pm, Monday through Thursday, and 9:00am until 1:00pm on Saturday, throughout the seven week period. Those students participated in a more extensive preparation sequence for the quantitative portion of the GRE.

Materials

Verbal Training

The same materials were used during the fall course to prepare for the verbal portion of the examination as were used in the spring and summer courses.

Quantitative Training

Two quantitative sections of each of two GRE tests (92-1 and 92-2) were analyzed with the goal of identifying the smallest unit of the skills and subskills with which students should presumably become fluent in order to do well on the GRE. Each question on the examination was analyzed in terms of its component parts (e.g., percentages, inequalities, volume, area, etc.). Once these components were noted, the most frequently occurring skills were identified in terms of percentage of possible occurrences on each examination (e.g., the skill of calculating area occurred in 15% of the 60 quantitative questions). For details of this analysis, see Appendix G.

After this analysis, a drill was created for each of the 42 pinpointed skills, in the order they were presented in Mathworks, the instructional text used in the course. Using Exam-in-a-Can software (International Publishing Services, 1995), a new series of 42 drills was created, one drill (with multiple versions) for each of the identified skills on the GRE (Appendix H). Each drill consisted of 20 free-response problems (i.e., they were not given choices from which to select the correct answer; each answer was generated by the student) addressing a single mathematical concept (e.g., 20 questions covering the addition of fractions) (Appendix I). Approximately 20 versions of each drill were created.

In the following manner, the drills were modified from the spring/summer design to increase ease of use and to enable students to focus more specifically on individual skills. The spring/summer drills were separated into four categories (basic math, fractions, percents, and decimals), but each category had at least four different subskills included (e.g., addition, subtraction, multiplication, and division). The new drills were separated by each of those subskills. The number of practice problems for each basic skill in both versions of drills was roughly the same, yet the new set extended the practice to cover the more complex skills and of algebra and geometry.

Modeling the procedures from the original set of fluency drills, the same exemplary undergraduate student completed each drill until she achieved 100% three consecutive times. The last (most fluent) performance served as the fluency aim for the students in the GRE preparatory course. However, given the number of drills and the inclusion of the more complex skills, students were only required to achieve 90% of the fluency aim on each drill. Students were instructed to adhere to the following three-step format: (1) read the relevant section of Mathworks, (2) complete all of the practice problems for that section of Mathworks, and (3) achieve fluency on the relevant 20-question drill. All students achieved the fluency aims from the basic skills through algebra, and four of the six completed all 42 drills. The two students who did not complete all of the geometry drills completed the geometry sections in Mathworks and at least one practice drill. Thus, all students had exposure to all skills. Although the content and the length of time required to complete the drills differed substantially between the two sets of drills (spring/summer and fall versions), the general procedures for both remained the same.

Results

Six of the eight enrolled students completed all requirements. All received the $75 rebate for attending and actively participating a minimum of 92% of the time. The results reported below are limited to those who completed the course.

The mean GRE-T (combined verbal and quantitative) pretest score was 933 and the mean posttest score was 985 (Table 3) for an overall improvement of 52 points (Figure 5). The scores ranged from 590 to 1280 for the pretest and 670 to 1390 for the posttest. The mean pretest and posttest scores for the verbal component were 468 and 470 respectively (Table 3), for a mean improvement of 2 points (Figure 5). The verbal pretest scores ranged from 320 to 650, and the posttest scores ranged from 340 to 690. The mean pretest and posttest scores for the quantitative component were 465 and 515 respectively (Table 3), for a mean improvement of 50 points (M=50, SD=33.5), $t(7)=3.66$, $p < .05$ (Figure 5). Scores on the quantitative pretest ranged from 270 to 630 and posttest scores ranged from 330 to 700.

Table 3

Mean Pretest and Posttest Scores for Fall Course

	Pretest	Posttest	Improvement	N
GRE-V	468	470	**2**	6
GRE-Q	465	515	**50***	6
GRE-T	933	985	52	6

* p < .05

Four of the six students completing the course took the October administration of the GRE. The mean improvement on the verbal portion of the test for these students was 45 points, and the mean improvement for the quantitative component was 92, for a GRE-Total mean improvement of 137 points (Figure 6). GRE-T pretest scores ranged from 790 to 1280 ($\underline{M}$ = 1008) and posttest scores ranged from 960 to 1410 ($\underline{M}$ = 1145).

Students in each of the courses completed evaluations of both the materials and the course. With the exception of one of the study materials (Think Fast), all received favorable ratings, as did the overall course (Figures 7 - 12).

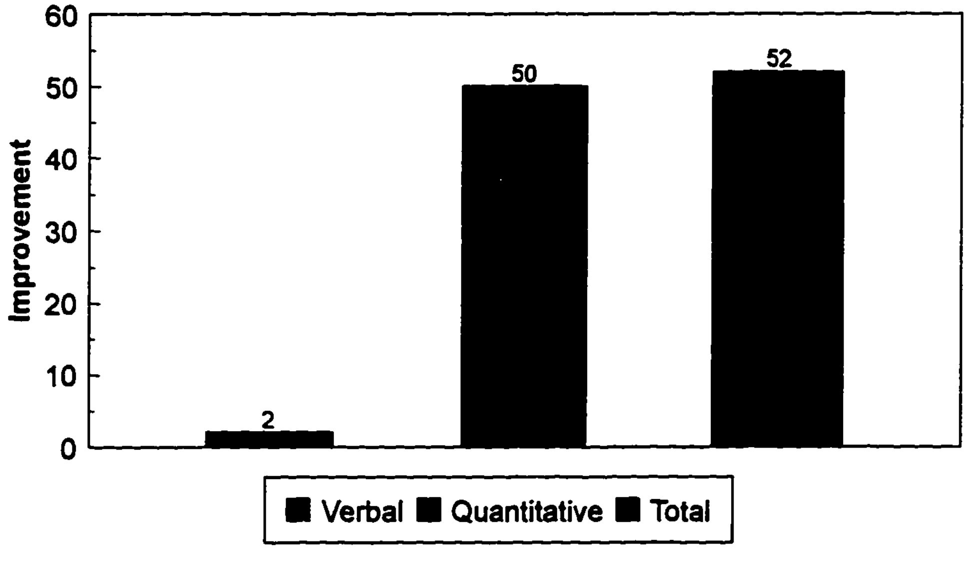


Figure 5. Mean Verbal, Quantitative, and Total Improvement From Pretest to Posttest for All Students Enrolled in the Fall Course.

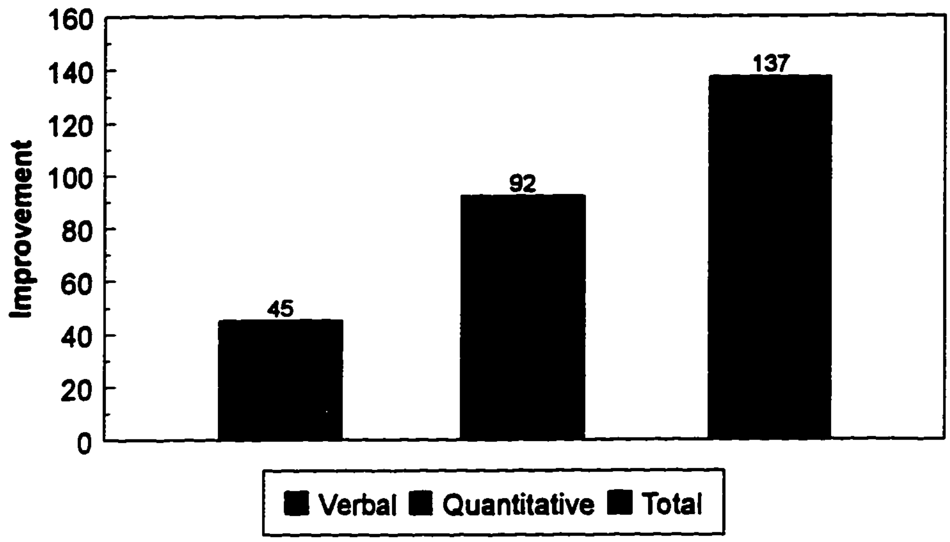


Figure 6. Mean Verbal, Quantitative, and Total Improvement From Pretest to Actual GRE for Students Enrolled in the Fall Course.

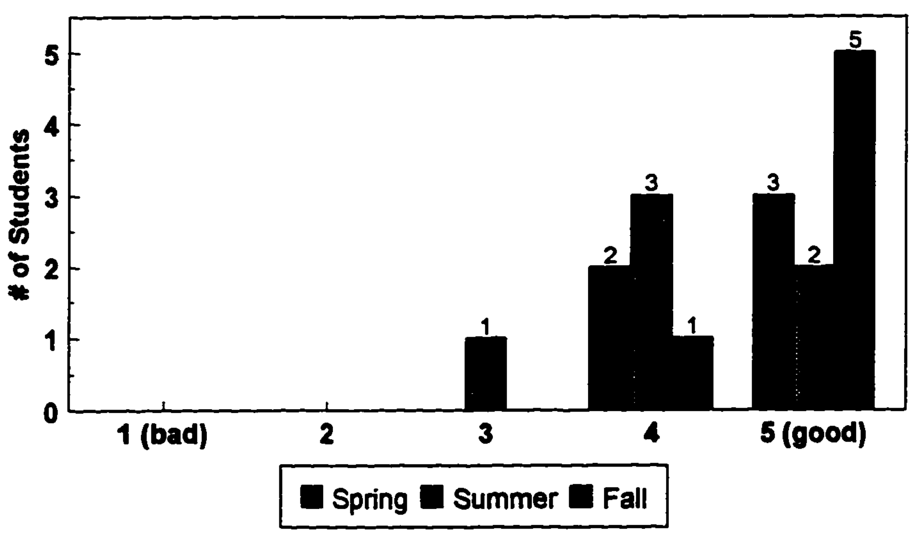


Figure 7. Students' Rating of the Barron's Book.

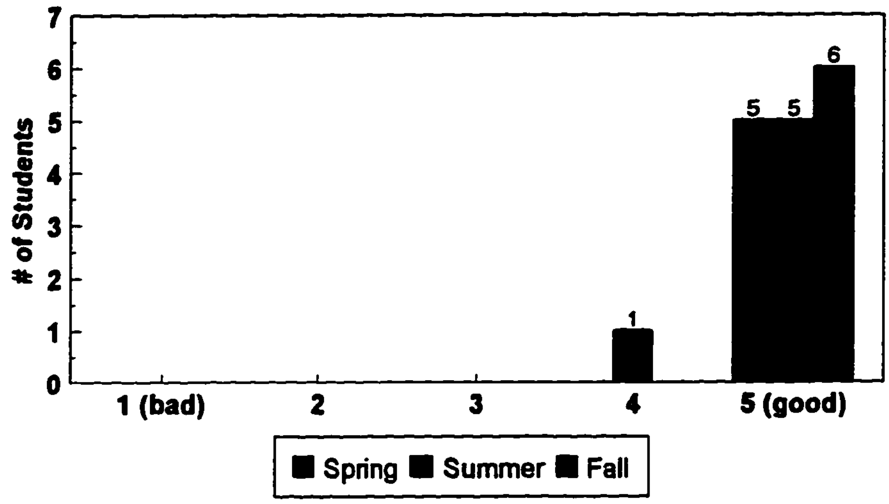


Figure 8. Students' Rating of the Mathworks Book.

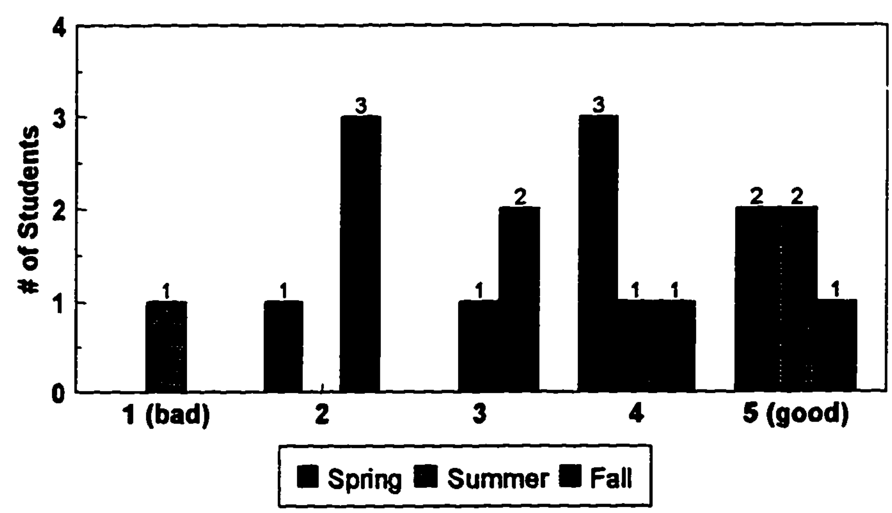


Figure 9. Students' Rating of the Think Fast Program.

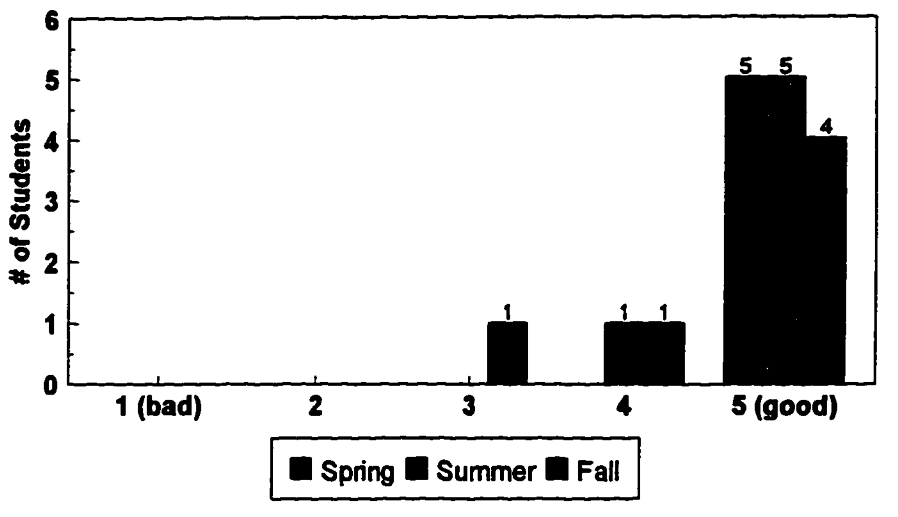


Figure 10. Students' Rating of Exam-in-a-Can Fluency Drills.

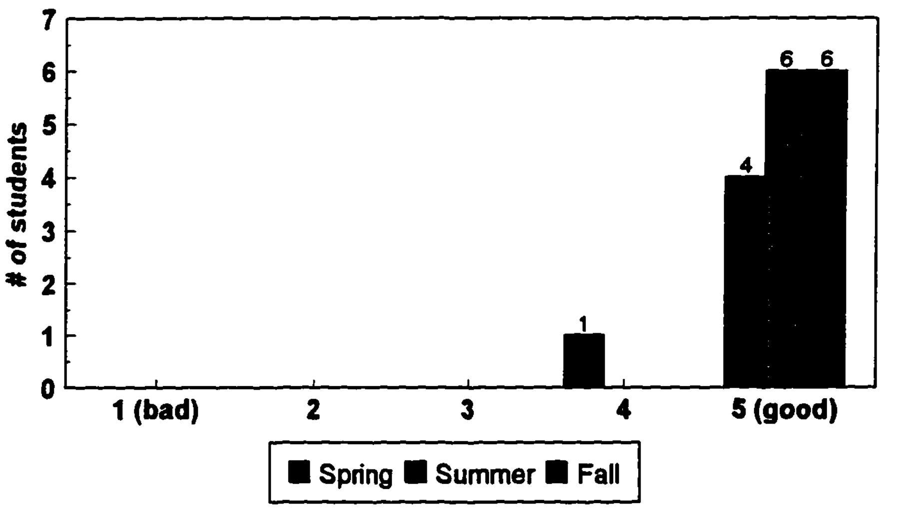


Figure 11. Students' Rating of the Practice GREs.

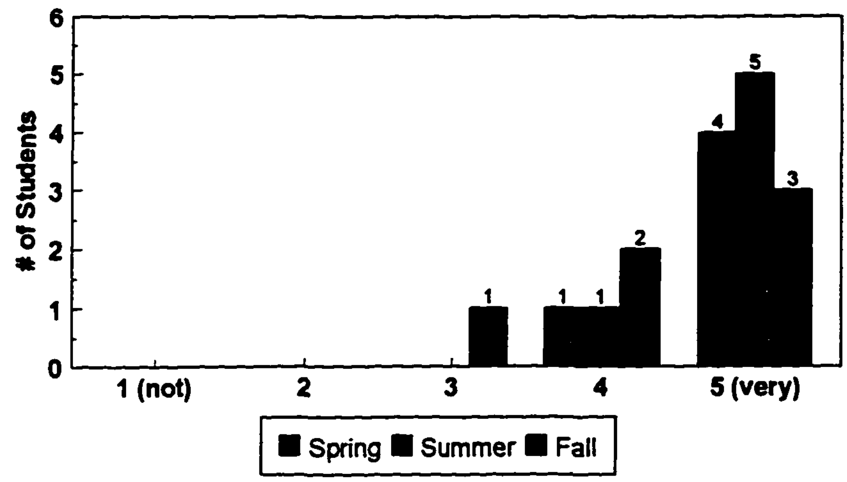


Figure 12. Students' Overall Rating of the GRE Preparation Course.

CHAPTER V

DISCUSSION OF FLUENCY TRAINING WITHIN GRE COURSES

The goal of this research was to determine whether fluency training could significantly impact performance on the quantitative skills tested by the GRE. Although students improved significantly from the pretest to the posttest on the quantitative portion of the GRE, both statistically and practically, it is not clear at this point to what extent the fluency drills are responsible for those improvements. Overall comparisons of improvements achieved in the 1995 series of preparation courses (including fluency training) and the 1994 series of courses (Miller, 1995) (in the absence of fluency training) were not significant (Appendix M).

There are two possibilities as to why the fall version of the drills did not have the expected impact on the GRE scores, when the differences between the two sets of drills are examined along with the structure of the fall course vs. the spring and summer courses. One was that the 42 drill sequence took too much time to complete given the total number of hours available for students to focus on quantitative skills (i.e., time to completion exceeded the available 60 hours in some cases). Students reported that although they thought the drills were very beneficial, the work was exhausting and too demanding for the time available. Another point is related to the posttest under-predicting the actual performance on the GRE. This may be due in part to fatigue as these students took the posttest during the GRE course late in the evening (8:00pm) after a full day of classes and/or work, as opposed to taking the actual GRE on a Saturday morning (8:00am), and the posttest usually has a tendency to overpredict the actual GRE scores, rather.

However, it may instead be that the changes from the spring/summer set of drills were not an improvement. The main difference in the fluency drill sequences was that of focusing on the basic skills vs. training on all skills. The first two studies (spring and summer GRE courses) compromised by achieving fluency on basic skills and not training on more advanced skills, and the third experiment compromised by achieving less than exemplary fluency on each of the 42 skills, but at least all students had some training with the range of these skills. Given that choice, is it better to achieve exemplary performance on basic skills, or achieve sub-exemplary performance on all skills? It may be better to focus on the basic skills for the fluency training, in some combination of practice with the more complex skills of algebra and geometry. However, the data do not clearly support this theory.

It is interesting to note that the entering deficits in the pretest performance of the students in the preparation courses were not limited to the more complex skills of algebra and geometry. Students in the spring and summer courses needed approximately 60 hours to meet the fluency aims of the basic skills drills. Thus, it does seem reasonable that at least the place to start is basic math skills, even if direct training on the more advanced skills is needed, as it undoubtedly is.

CHAPTER VI

EVALUATING THE EFFECTS OF FLUENCY TRAINING: PART I

Introduction

This study was based on the procedures used within the GRE preparatory course. For the quantitative section of the GRE course, students achieved predetermined levels of fluency on a series 42 drills covering three areas: basic math, algebra, and geometry. The current study focused on evaluating the effectiveness of one segment of the basic math drills involving fractions. The purpose of the study was twofold: (1) to isolate one segment of the drills to determine how effective they are in improving performance, and (2) to determine if obtaining levels of speed, beyond accuracy, is advantageous to the students. Thus, we were attempting to determine the most effective and efficient method of preparation for the quantitative component of the GRE.

Methods

Subjects, Setting, and Materials

The subjects included six female junior and senior level psychology majors enrolled in either Psychology 360 "Concepts and Principles of Behavior Analysis" course or Psychology 460 "Survey of Behavior Analysis Research" at Western Michigan University. These subjects were recruited by the experimenter during class time. Subjects were selected based on interest expressed in training for the GRE. In order to participate, subjects could not have been previously or currently enrolled in the GRE preparation course, nor could they currently be registered in a mathematics course.

The study was presented as a way to help prepare for the quantitative portion of the GRE, and as an opportunity to earn ten optional activity points (OAPs) per hour of participation. OAPs are bonus points that can be used within the Psychology 360 and Psychology 460 courses. Students were informed of the necessity to complete all segments of the study in order to earn any OAPs. These points were awarded upon completion of the study.

All sessions of the study took place in a classroom on Western Michigan University's campus equipped with tables and desks with chairs. As the study was self-paced, the duration of the study varied for the individual subjects.

A section consisting of nineteen pages of Mathworks GRE-GMAT Math Review (Frieder, 1982) was used as a traditional method of preparing for the GRE. Mathematical drills were developed which consisted of seven different sets of 20-question free-response drills (Appendix J) generated using Exam-in-a-Can computer software (International Publishing Services, 1995). Each drill addressed a different set of fraction skills. The topics were: (a) Decimals to fractions, (b) fractions to decimals, (c) fraction lowest common denominator (LCD) and addition, (d) fraction subtraction, (e) fraction multiplication, (f) fraction division, and (g) fraction rules. The 20-question drills used as the dependent variable were a compilation of problems from each of the seven types of drills (Appendix K). These tests were also generated using Exam-in-a-Can (International Publishing Services, 1995). Subjects used answer sheets to record their answers to each drill and test. Each stage of the study was timed by the subjects individually using Spaulding quartz stopwatches.

Procedures

All subjects in the experimental group (four of the six) followed the same sequence of training. The sequence was as follows: First, each subject took a 20-question fractions test. Once completed, a second form of the same test was taken to account for test-retest reliability. Each subject was then given the sequence of 19 pages from Mathworks (Frieder, 1992). Subjects were instructed to read the text material and complete the practice problems. Once a subject finished this task, she completed a different form of the fractions test. The next step in the sequence was to complete and correct one of each of the seven drills. The drills were completed in the following order: Decimals to fractions, fractions to decimals, LCD and addition, subtraction, multiplication, division, and rules. Subjects received feedback regarding their performance during this segment. After this step of the sequence was completed, the subject took a fourth form of the fractions test. Following this, the subjects completed, the subject took a fourth form of the fractions test. Following this, the subjects achieved predetermined levels of fluency on each of the seven drills in the same sequence as that presented above (Appendix L). Each subject continued completing and correcting different versions of the same drill until she reached 100 percent accuracy within 10 percent of the time set as the fluency aim for that drill (e.g., if a fluency aim was 2:00, the minimum fluency level was 1:48). Only after becoming fluent on the preceding drill could the subject advance to the next drill in the sequence. Once fluent on all seven drills, each subject completed one final version of the fractions test.

Although subjects in the experimental group served as their own control, two of the six subjects served as additional controls. Each of these two subjects took the same number of fraction tests, but did not complete any of the training. The training was offered to both subjects upon completion of the sequence of five tests, but neither one chose to take advantage of this opportunity.

Results

All subjects in the experimental group increased their correct responses per minute from Fractions Test 1 to Fractions Test 5 by at least 2.32 corrects/minute (Figure 13). As Figure 14 illustrates, the largest increase in correct responses per minute by a control group subject was 0.61 corrects/minute. Thus, while the experimental group increased their rate of correct responses from the first administration to the fifth administration of the test, the control group did not (Figure

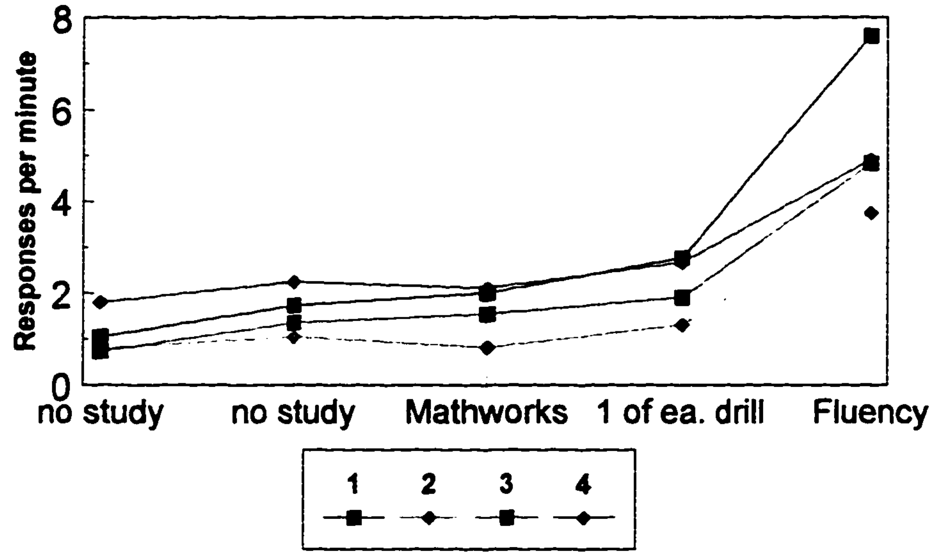


Figure 13. Correct Responses Per Minute on Fractions Test for Experimental Group.

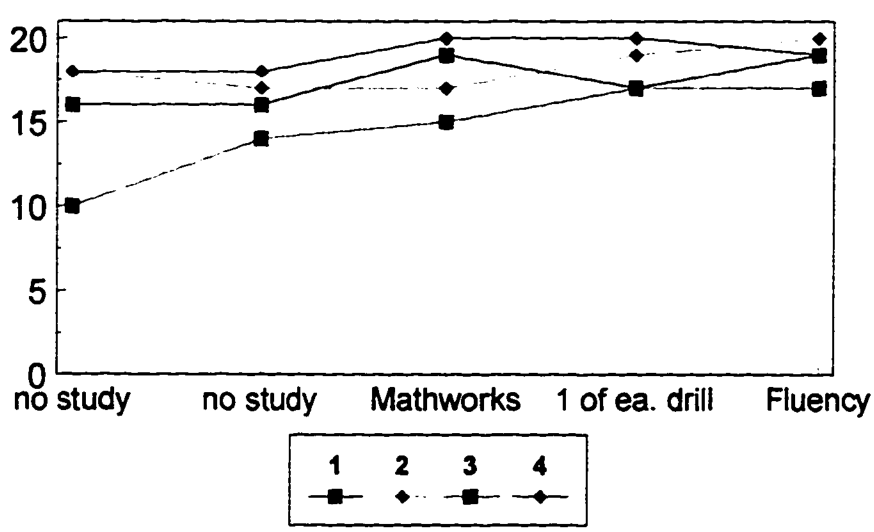


Figure 14. Correct Responses on Fractions Test for Experimental Group.

15). As Figure 13 indicates, there was no improvement in the number of correct responses per minute between the first test and the second test, thus eliminating the presence of a practice effect. There were also no increases in the number of correct responses per minute on the third fractions test, which was administered following the completion of the traditional method of study (i.e., reading Mathworks and completing the practice problems). This demonstrated that using a self-instructional text, in this case, did not improve performance. There was only a slight increase in the number of correct responses per minute and no increase in the number of total correct responses on Fractions Test 4, following completion of one of each of the seven drills (Figure 14). This illustrated that speed improved only slightly, while accuracy did not improve. The time required for completion of each of the drills (achieving fluency) varied for the individual subjects (Table 4).

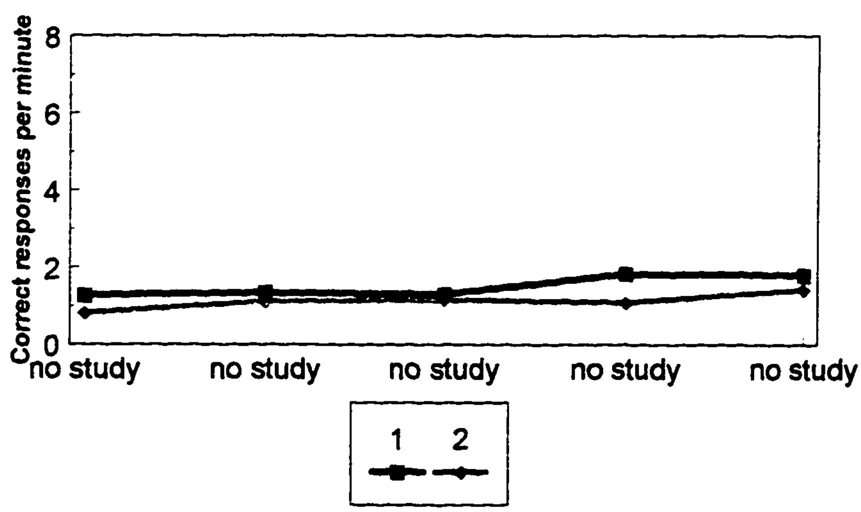


Figure 15. Correct Responses Per Minute on Fractions Test for Control Group.

Table 4

Number of Repetitions of Individual Drills to Achieve Fluency Aims

	Least repetitions	**Most repetitions**
Decimals to Fractions	6	16
Fractions to Decimals	8	23
LCD and Addition	3	5
Subtraction	2	14
Multiplication	9	25
Division	4	6
Rules	2	6

Incorrect responses per minute did not differ between the subjects or from one fractions test to another. This is probably due to the fact that incorrect responses per minute were relatively low at the beginning of the experiment, and remained low throughout the study.

Discussion

The results of this study demonstrate that fluency training with fractions will increase students' performance speed in terms of correct responses per minute while none of the other training portions of the sequence had that effect. This is important as the GRE is a timed test. However, the generative effects of this instruction were not measured, and may be a more important issue than the increase in speed. As fluency training takes a considerable amount of time to administer, the possibility of obtaining generalization to more complex skills becomes an important consideration. At this point, it is unclear the extent to which efficiency is gained by incorporating fluency training into the GRE courses. Further research is necessary to compare fluency training with other methods of instruction.

CHAPTER VII

EVALUATING THE EFFECTS OF FLUENCY TRAINING: PART II

Introduction

The last experiment in this series was another attempt at evaluating the sequence of fluency drills. Two undergraduate psychology students completed the entire set of 42 drills, achieving both accuracy and speed criteria for each drill. Given the lack of time to complete the drills within the three weeks of the GRE course which were dedicated to this task, the goal of this research was to discover whether students would achieve greater improvements from pretest to posttest if they had sufficient time to complete all drills.

Methods

The procedures for completing the drill sequence were essentially identical to those of the fall semester GRE course, with the exception that these students had 13 weeks of the winter semester to complete the drills, and they were required to reach 100% of the exemplar's fluency aim whereas the fall students had a goal of 90% of the exemplar's performance. Both students focused solely on the quantitative portion of the GRE.

Results

Student A spent approximately 40 hours on the drills and another 10 hours working through the review and practice problems in Mathworks. Student B spent approximately 55 hours on the drills and another 10 hours working through the review and practice problems in Mathworks. Student A had a pretest score of 730 and a posttest score of 690, for an overall change of -40 points (Figure 16). Student B had a pretest score of 510 and a posttest score of 590, for an overall improvement of 80 points. When asked to rate the value of the fluency drills, both students gave them a rating of 5 on a scale of 1 to 5, with 5 being the highest score.

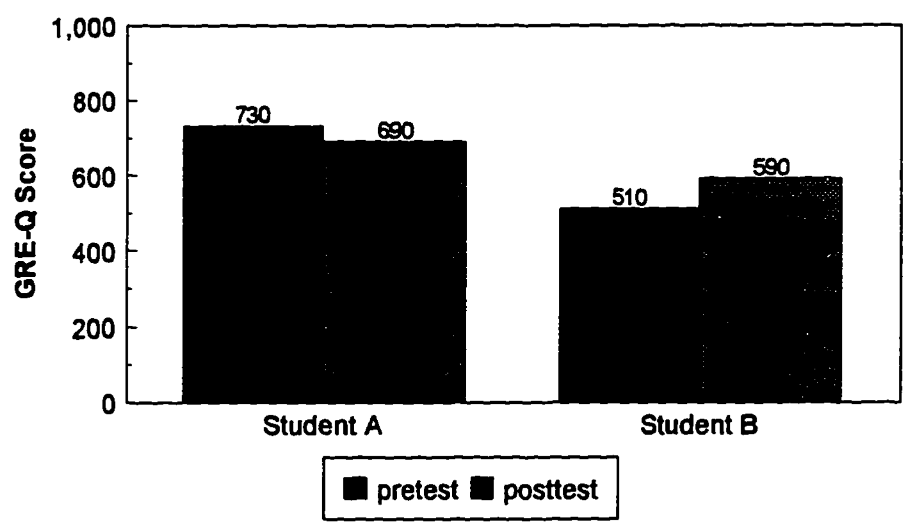


Figure 16. Mean GRE-Q Pretest to Posttest Scores for Fluency Drill Students.

Discussion

The results for the students completing the fluency drills over the course of the winter semester are somewhat ambiguous. Although Student B had an improvement of 80 points, Student A had a difference of -40 points from pretest to posttest. Even though both of these students spent at least double the amount of hours on the drills than any of the students in the fall course, proportional benefits were not attained.

One issue may be Student A's pretest score which was very high (730 on an 800 point scale). This score was considerably higher than that of the highest pretest score of students in the fall GRE-preparation course (730 vs. 630 respectively). However, given the amount of time spent on the drills, one might expect that his performance would at least approach that of the exemplary student (750 on an 800 point scale). Student A and Student B were both required to achieve 100% of the speed criterion set by the exemplar, whereas the students in the fall GRE course were only required to achieve 90% of the speed criterion, which may be another reason to expect higher gains. Instead, Student A's performance dropped 40 points, which may simply be a reflection of the variability typically seen on the GRE, and Student A did not achieve impressive improvements beyond any found in the GRE courses.

CHAPTER VIII

CONCLUSIONS

The reported studies were part of a thematic line of research focusing on improving students' performance on the GRE. The results obtained in both the 1994 and 1995 series of courses far exceeded any results reported in the literature on GRE-preparation. No other methods of preparation produced results of this magnitude, nor of any statistical significance. This is not surprising, as the hours of preparation time reported in the literature ranged from 2.9 to 9.4 hours, compared to approximately 140 hours per course in the present research. It is unlikely that the significant pretest-posttest improvements achieved in these courses were due to mere variability, based on the data regarding test-retest reliability (Wilson, 1985).

Another issue is that of the ability of the GRE to predict success in graduate school. There is a great amount of variability in results within the published literature on this topic. Regardless of whether or not the test has predictive validity, there is no reason to assume that training on basic skills as done in these courses would invalidate the predictive validity of the GRE.

Regarding ways to teach or remediate mathematics skills, research evaluating the use of fluency training is novel. The value of the "drill and practice" method of improving quantitative skills has been reported, but not in the absence of other intervention components. Although the method of preparation for the quantitative portion of the GRE used in these courses is not directly comparable to any of the literature reported on traditional methods of teaching mathematics, the significant results suggest the fluency drills along with instructional texts may be an effective method for teaching remedial mathematics in other settings. One such application may be in preparation for other standardized tests such as the Scholastic Aptitude Test (SAT) which, like the GRE, is published by Educational Testing Services.

Lastly, there is the issue of fluency. Johnson and Layng (1992) discussed the effects of fluency training on the development of new, complex skills. The theory of generative instruction has great potential within the context of the GRE-preparation courses, considering the limited time available to remediate or teach quantitative skills. The assumption is that training on the basic skills better prepares students to learn more complex skills (e.g., fluent performance on addition, subtraction, and multiplication better enable a student to learn to factor an equation). However, the lack of published literature on fluency and related issues such as generative instruction prevents meaningful comparisons of other research with the effects of the fluency drills used in the GRE-preparation courses.

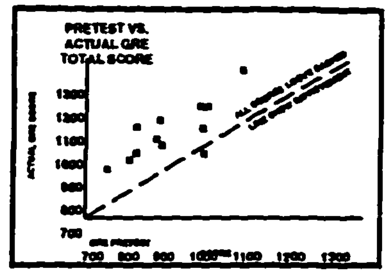
Based on results from this line of research, it appears that this style of intensive, extensive, structured preparation sequence is at least an effective method of preparing graduate school candidates for the GRE. As research is continually conducted to evaluate both materials and methods of instruction, students benefit not only by improving their chances of acceptance to graduate school, but also by improving their performance on skills which have value outside of standardized testing requirements.

Appendix A

Recruitment Flyer Advertising GRE Course

GRE Preparation Course

for Verbal and Quantitative Portions of the Graduate Records Examination



- **Low GRE scores can severely damage your chances of being accepted in the graduate program of your choice! Many graduate programs require at least a 500 on both the verbal and quantitative sections of the exam.**
- **Solid preparation for the GRE improves your chances of doing well!**
- **It is _very_ difficult to motivate yourself to do the studying for the GRE that you should do ... and want to do.**

This course provides the structure for the hard work you need to do. It has helped other WMU students with their preparation — their actual GRE test scores showed significant improvement over pretest scores, as shown in the graph above.

YOU MUST REGISTER BEFORE THE FIRST DAY OF CLASS!

Sponsors: Department of Psychology and Office of Conferences & Institutes

When: 8:00 a.m. to noon
Monday through Friday
Spring: May 1 - June 16
Summer: June 28 - August 15

Cost: $385, includes course fee and comprehensive materials
(If you miss two or fewer classes you'll get $75 back!)

For further information about the content of the class, call Pam Vunovich, 345-7553

To register, call the Office of Conferences and Institutes at 387-4174.

GRE Preparation Course Registration

Name ______________________________ SS# ______________

Address ____

City ______________________ State ________ ZIP ________

Telephone (____) ______________________

Please register me for ☐ Spring ☐ Summer

Payment (Fee: $385)

☐ Enclosed is my check or money order, payable to Western Michigan University.

☐ Please charge my ☐ Visa ☐ MasterCard ☐ Discover

account # exp. date authorized signature

Return form and payment to: Office of Conferences and Institutes, Western Michigan University, Kalamazoo, MI 49008. With credit card payment, this form may also be faxed to Office of Conferences and Institutes, (616) 387-4189.

For office use only 23-324035-8532

mo/ck # ________ cash ________ credit ________ amt. received ________

date ________ auth/recpt # ________ issued by ________

Appendix B

Informed Consent Form

Western Michigan University
Department of Psychology
Principal Investigator: Pamela L. Vunovich
Advisor: Richard W. Malott, PhD

I give my permission to Pamela L. Vunovich to use the data collected during this GRE preparation course in her dissertation and in professional presentations and articles. She is collecting these data to evaluate the effectiveness of this course in helping students prepare for the GRE.

I understand that all the information collected from me is confidential. That means that my name will not appear on any papers on which this information is recorded. All forms will be coded, and the principal investigator will keep a separate master list with the names of the participants and the corresponding code numbers.

I understand that I may withdraw my permission at any time during this course without prejudice or penalty. If I have any questions or concerns about this study, I may contact Richard W. Malott, PhD at 372-1268. I may also contact the Chair of the Human Subjects Institutional Review Board or the Vice President for Research with any concerns that I may have (387-8293 and 387-8298, respectively). My signature below indicates that I understand the purpose and requirements of the study and that I agree to participate.

______________________________ ______________

Signature Date

Appendix C

Course Syllabus

GRE Preparation Course

Fall, 1995

Time: M - Th. 6:00 p.m. - 10:00 p.m.
Sat. 9:00 a.m. - 1:00 a.m.

Dates: Aug. 28 - Oct. 5

Rooms: 304 North Hall on East Campus

Instructor: Dr. Richard Malott

Assistants: Pam Vunovich 345-7553 or 387-4491 (do not leave messages at 2nd number)
Dana Pososki

Rebate Policy: If you miss two or fewer classes and participate actively in all the others, you will earn a $75 rebate after all *special course materials have been returned. As an extra incentive to get to class on time, each occasion you are more than 10 minutes late, it will count as one quarter of an absence. (It really is that important that you are there at 6:00 p.m. -- we have a busy semester ahead of us, and we don't want you to fall behind.)

Course Structure: This course will provide the structure for the hard work you need to do. The class will meet Monday through Thursday from 6:00 p.m. until 10:00 p.m., and Saturdays from 9:00 a.m. until 1:00 p.m. (Aug. 28 - Oct. 5). You will not receive credit for this course; however, prompt attendance is essential. Attendance will be the key factor in putting in the requisite amount of work. Studying will take place in a computer lab as well as a classroom in North Hall on East Campus off of Oakland Drive.

Details: Each of the participants will focus on the quantitative portion of the study materials for half of the semester, and the verbal portion of the study materials for the other half of the semester. Half of the participants will do quantitative first, and then verbal, and the other half will have the opposite schedule.

Course Rationale: If you receive good scores on the posttest, you should take the GRE exam at the end of this course.

**special course materials include: Mathworks book, fluency drills, daily logs, and any other materials used during the course that are purchased with the intent of staying with the GRE course.*

Appendix D

Course Evaluation

GRE Preparation Course

Evaluation

1. Which of the following courses did you attend (circle one) ?

Spring Summer Fall

2. How would you rate the following materials in the course in terms of usefulness? (Please check the appropriate box in the table below:

	How helpful was each study tool?				
Materials	1(not)	2	3	4	(very)5
Barron's					
Think Fast disk					
Fluency drills					
Mathworks book					
Practice GRE exams					

3. How helpful was the course?

1 not at all 2 3 4 5 very

4. Are you pleased with your progress?

1 not at all 2 3 4 5 very

5. What, if anything, would you do to improve the course?

Verbal Drills:

Appendix E

Example of Spring Fluency Drills

GRE Preparation Course

Fluency Drill 3

Decimals

5/18/1995 | Page 1 | Form 1

1. Add: 5 + 17.24

2. Add: 4919 + 51.933

3. Add: 0.73 + 1.798

4. Add: 36.954 + 8.69

5. Add:

$$\begin{array}{r} 29.1623 \\ \underline{+\ \ 6.3412} \end{array}$$

6. Add: 6.42 + 9.83 + 7.67

7. Add: 0.18 + 448 + 8.2 + 0.263

8. Add:
$$\begin{array}{r} 93.28 \\ 460.816 \\ \underline{+\ \ 4.9842} \end{array}$$

9. Add: $33.69 + $1.14

10. Add:
$$\begin{array}{r} \$31.34 \\ \underline{+\ \ 4.40} \end{array}$$

11. Subtract: 344.42 - 16.5

12. Subtract: 0.82 - 0.75

13. Subtract: 15.41 - 1.356

14. Subtract: 60.0002 - 22.9251

15. Subtract:
```
   15.4
 - 2.0094
```

16. Find: 12.4 - 0.246 - 0.72

17. Subtract: $56.65 - $47.98

18. Subtract:
```
   $58.58
 -  44.20
```

19. Estimate.
```
   69.26
 - 59.23
```

20. Multiply: 0.82 X 0.5

21. Multiply:
```
   0.92
 X 0.2
```

22. Multiply: 5.51 x 0.019

23. Multiply: 0.560 · 1.1

24. Multiply: 0.39 X 100,000

25. Multiply: 0.38 · 10,000

26. Multiply: $57.71 X 85

27. Multiply:
$$\begin{array}{r} \$89.52 \\ \underline{X \quad 26} \end{array}$$

28. Divide: $\frac{0.204}{0.34}$

29. Divide: $0.035\overline{)0.1575}$

30. Divide: 9.911 ÷ 1.87

31. Divide and round to the nearest hundredth: 1263.312 ÷ 18

32. Divide: 613.8 ÷ 31

33. Divide: 4040 ÷ 0.8

34. Divide: $\frac{245}{0.35}$

35. Divide: $0.2\overline{)1612}$

36. Divide: 40 ÷ 0.13 and round the answer to the nearest hundredth.

37. Round the quotient $\frac{37}{0.31}$ to the hundredths place.

38. Divide: 2.91 ÷ 10,000

39. Divide: $\frac{1.195}{10}$

40. Divide: \$11.52 ÷ 24

41. Divide: 86 $\overline{)\$16.34}$

42. Estimate using compatible numbers.
9.4 x 8.9

43. Estimate by rounding to the nearest ten: 49.33 x 28.77

44. Estimate by rounding to the nearest ten: $\frac{109.53}{12.5}$

45. Estimate 1.91 x 0.093.

46. Find: 56.6 − 8.4 · 0.88

47. Simplify: 5.7 X 9.7 + 1.2 ÷ 2.0

48. Write 54.378 in expanded form.

49. Insert <, >, or = to form a true statement.
77.334 ___ 77.334001

50. Write a true sentence using < or >: 1.30 ___ -0.20

51. Which number is larger? 19.76 or 19.762

52. Which of 38.1 and 38.03 is larger?

53. Give the word name for 443.41.

54. Write 0.8025 in words.

55. Add the following and write as a decimal.
four hundred nine thousandths + eight and three tenths + four

56. Write the decimal in standard form.
forty-two and twenty-three hundredths

57. Write the expression five and fifty-six ten-thousandths as a decimal.

58. Draw a model for 0.14.

59. Round 149.851 to the nearest tenth.

60. Round 0.634194 to the tenths place.

61. Round 37.354 to the nearest tenth.

62. Insert <, >, or = to form a true statement.

$\frac{7}{40}$ ___ 0.17

63. Write 0.7 as a fraction.

64. Write 0.29 as a fraction.

65. Write 0.85 as a reduced fraction.

66. Write 3.20 as a reduced fraction.

67. Write as a reduced fraction: 0.025

68. Write 0.53 and 0.0013 in fraction form with equal denominators.

69. Write 5.35 as a mixed number with a fraction reduced to lowest terms.

70. Write 7.912 as a mixed number.

71. Write as a reduced fraction: 1.10

72. ~~Write 7.34 as a~~ completely reduced mixed number.

73. ~~Write $0.\overline{54}$ as a reduced fraction.~~

74. Write as the indicated quotient of two integers in completely reduced form: $0.0\overline{2}$

75. Write 0.9595... ~~as a ratio of two integers.~~

76. Find the fraction ~~that is equivalent to the repeating decimal 0.291291291... .~~

77. Write $\frac{8}{10}$ as a decimal.

78. $\frac{6}{10}$ = _____ as a decimal.

79. Write as a decimal: $\frac{11}{1000}$

80. Write $4\frac{975}{10000}$ as a decimal.

81. Write $\frac{29}{100}$ as a decimal.

82. Write $\frac{3}{16}$ as a decimal.

83. Write $\frac{12}{25}$ as a decimal.

84. Write $\frac{5}{6}$ as a decimal.

85. Find the decimal equivalent of $\frac{23}{33}$.

86. Which number is in the tenths place?
932.546

87. Write the decimal in words: 541.41

88. Write the decimal in standard form.
forty-one and thirty-seven thousandths

89. Insert <, >, or = to form a true statement.
35.732 ___ 35.732001

90. Round 80.742 to the nearest hundredth.

91. Round to the nearest dollar to estimate.
\$17.30 + \$16.57

92. Add: 6 + 25.29

93. Add: 66.954 + 9.69

94. Subtract: 647.42 - 18.5

95. Find: 47.1 - 0.448 - 0.64

96. Write as a decimal: $\frac{5}{18}$

97. Estimate using compatible numbers.
413 ÷ 8

98. Estimate using compatible numbers.
6.99 x 0.77

99. Multiply: 53.6 x 0.011

100. Multiply: 0.042 X 100,000

101. Multiply: $86.19 X 63

102. Divide: 1218 ÷ 0.3

103. Divide: 33.8 ÷ 0.26

104. Find: 79.8 - 2.5 · 0.62

Appendix F

Quantitative Data Collection Form

Individual Data Tables

Name:													
	Date:												
Drill:	/	/	/	/	/	/	/	/	/	/	/	/	/
	Occasion and Form Number:												
	Aim	1___	2___	3___	4___	5___	6___	7___	8___	9___	10___	11___	12___
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													

Appendix G

Analyses of Quantitative Portion of the Graduate Record Examination

	Analysis of GRE								
	92-1								
	Quantitative								
			inc.	%c				inc.	%c
1	Quant Comparison	dec/frac			1	Quant Comparison	frac		
2	Quant Comparison	word			2	Quant Comparison	avg		
3	Quant Comparison	alg/word			3	Quant Comparison	word		
4	Quant Comparison	alg			4	Quant Comparison	exp		
5	Quant Comparison	geom			5	Quant Comparison	word		
6	Quant Comparison	alg/exp			6	Quant Comparison	geom		
7	Quant Comparison	alg/exp			7	Quant Comparison	alg/frac		
8	Quant Comparison	geom			8	Quant Comparison	geom		
9	Quant Comparison	alg/exp			9	Quant Comparison	alg/%		
10	Quant Comparison	geom			10	Quant Comparison	alg		
11	Quant Comparison	integers			11	Quant Comparison	geom		
12	Quant Comparison	alg/frac			12	Quant Comparison	alg/frac		
13	Quant Comparison	alg/exp			13	Quant Comparison	geom		
14	Quant Comparison	geom/word			14	Quant Comparison	alg/frac		
15	Quant Comparison	frac/exp			15	Quant Comparison	geom		
16	Discrete Quantitative	word/%			16	Discrete Quantitative	exp/frac		
17	Discrete Quantitative	alg			17	Discrete Quantitative	dec		
18	Discrete Quantitative	mult/int			18	Discrete Quantitative	alg		
19	Discrete Quantitative	alg/int			19	Discrete Quantitative	alg/exp		
20	Discrete Quantitative	geom			20	Discrete Quantitative	alg/geom		
21	Data Interpretation	data int.			21	Data Interpretation	data int		
22	Data Interpretation	data int/avg			22	Data Interpretation	data int/div		
23	Data Interpretation	data int			23	Data Interpretation	data int/%		
24	Data Interpretation	data int/alg/frac			24	Data Interpretation	data int		
25	Data Interpretation	data int/%			25	Data Interpretation	data int		
26	Discrete Quantitative	geom/alg			26	Discrete Quantitative	num lin/alg/frac		
27	Discrete Quantitative	geom			27	Discrete Quantitative	word/mult		
28	Discrete Quantitative	word/alg/frac			28	Discrete Quantitative	geom/sq rt/frac		
29	Discrete Quantitative	alg/frac			29	Discrete Quantitative	alg/frac		
30	Discrete Quantitative	alg/dec/sq rt/exp			30	Discrete Quantitative	word/geom		

Appendix H

List of Fall Fluency Drills and Fluency Aims

Fluency Drills & Aims

#	Unit	Drill	Aim
1	**Basic Math**	Addition	2:30
2		Subtraction	4:35
3		Multiplication	5:30
4		Division	5:51
5		Factors	5:22
6		Places	1:20
7		Primes	3:14
8		Rounding	1:30
9	**Decimals**	Addition	3:13
10		Subtraction	4:15
11		Multiplication	2:50
12		Round and Compare	:51
13		Decimals to Fractions	1:23
14		Fractions to Decimals	2:19
15	**Fractions**	LCD and Addition	3:42
16		Subtraction	4:22
17		Multiplication	3:14
18		Division	3:08
19		Rules	1:26
20	**Percents**	Solving Problems	2:15
21		Percents to Decimals/Decimals to Percents	1:22
22	**Algebra**	Order of Operations	2:56
23		Exponents	1:00
24		Evaluating Algebraic Expressions	2:12
25		Signed Numbers	1:24
26		Adding and Subtracting Polynomials	4:16
27		Multiplying Polynomials	2:08
28		Solving Equations	3:46
29		Equations with Fractions	2:43
30		Inequalities	4:22
31		Factoring Polynomials	6:00
32		Quadratic by Factoring	1:11

33		Factoring Special Polynomials	2:25
34		Squares	1:22
35		Square Roots: Add, Subt, Mult, Div.	3:28
36	**Geometry**	Angles and Lines	2:14
37		Polygons	3:08
38		Triangles	3:07
39		Quadrilaterals	2:43
40		Perimeter	3:10
41		Coordinates	2:47
42		Volume	2:47

Appendix I

Example of Fall Fluency Drills

GRE Preparation Course

Algebra: Equations with Fractions

10/5/1995 Page 1 Form 26

1. Add: $\frac{5}{4(x + 4)} + \frac{7}{4(x + 4)}$

2. Add and give the answer in completely reduced form: $\frac{-2x - 3}{3x} + \frac{3x + 3}{3x}$

3. Add: $\frac{5}{x + 8} + \frac{2}{x - 8}$

4. Add and give the answer in completely reduced form: $\frac{4x}{y^4z^5} + \frac{-4}{y^2z^3}$

5. Add: $\frac{4}{x} + \frac{3}{x^2}$

6. Find the difference: $\frac{u + 9}{x} - \frac{u - 4}{x}$

7. Subtract: $\frac{5}{7(x + 7)} - \frac{1}{7(x + 7)}$

8. Subtract and give the answer in completely reduced form: $\frac{6x - 3}{x^2 - 64} - \frac{5x - 11}{x^2 - 64}$

9. Subtract and give the answer in completely reduced form: $\frac{9}{x^2 + 4x - 12} - \frac{6}{x - 2}$

10. Subtract: $\frac{x}{x - 3} - \frac{4}{5}$

11. Perform the indicated operations: $\frac{x}{x^2 - 16} + \frac{4}{x^2 - 16}$

12. Add: $\frac{7}{3(x + 8)} + \frac{5}{3(x + 8)}$

13. Add and give the answer in completely reduced form: $\frac{-x - 4}{8x} + \frac{3x + 4}{8x}$

14. Add: $\frac{7}{x + 1} + \frac{6}{x - 1}$

15. Add and give the answer in completely reduced form: $\frac{8x}{y^2z^5} + \frac{-7}{y^3z^2}$

16. Add: $\frac{5}{x} + \frac{8}{x^2}$

17. Find the difference: $\frac{a + 3}{b} - \frac{a - 1}{b}$

18. Subtract: $\frac{4}{9(x + 8)} - \frac{3}{9(x + 8)}$

19. Subtract and give the answer in completely reduced form:
$$\frac{-4x + 2}{x^2 - 4} - \frac{-3x}{x^2 - 4}$$

20. Subtract and give the answer in completely reduced form:
$$\frac{3}{x^2 - x - 42} - \frac{2}{x - 7}$$

GRE Preparation Course

Algebra: Equations with Fractions

10/5/1995 **Page 1** **Form 26**

[1] $\frac{3}{x + 4}$ ______

[2] $\frac{1}{3}$ ______

[3] $\frac{7x - 24}{x^2 - 64}$ ______

[4] $\frac{4x - 4y^2z^2}{y^4z^5}$ ______

[5] $\frac{4x + 3}{x^2}$ ______

[6] $\frac{13}{x}$ ______

[7] $\frac{4}{7(x + 7)}$ ______

[8] $\frac{1}{x - 8}$ ______

[9] $\frac{-6x - 27}{x^2 + 4x - 12}$ ______

[10] $\frac{x + 12}{5x - 15}$ ______

[11] $\frac{1}{x - 4}$ ______

[12] $\frac{4}{x + 8}$ ______

[13] $\frac{1}{4}$

[14] $\frac{13x - 1}{x^2 - 1}$

[15] $\frac{8xy - 7z^3}{y^3z^5}$

[16] $\frac{5x + 8}{x^2}$

[17] $\frac{4}{b}$

[18] $\frac{1}{9(x + 8)}$

[19] $-\frac{1}{x + 2}$

[20] $\frac{-2x - 9}{x^2 - x - 42}$

Appendix J

Example of Fractions Drills

GRE Preparation Course

Fractions: LCD and Addition

12/10/1996 Page 1 Form 1

1. Find the LCD: $\frac{1}{3} + \frac{5}{12} + \frac{1}{8}$

2. Add: $\frac{2}{11} + \frac{1}{11}$

3. Add: $\frac{5}{11} + \frac{1}{11}$

4. Find $\frac{7}{10} + \frac{1}{10} + \frac{6}{10} + \frac{8}{10}$. Give your answer as a completely reduced proper fraction or mixed number.

5. Find $\frac{5}{10} + \frac{7}{10}$. Give your answer as a completely reduced proper fraction or mixed number.

6. Add: $1\frac{7}{13} + 3\frac{12}{13}$

7. Find: $\frac{5}{8} + 5\frac{4}{8} + 3 + \frac{4}{8}$

8. Add. Write a mixed numeral for the answer.

$$\begin{array}{r} 7\frac{3}{4} \\ +\ 6\frac{3}{4} \\ \hline \end{array}$$

9. Add: $\frac{4}{5} + \frac{7}{10}$

10. Find the LCD and the sum: $\frac{5}{7} + \frac{9}{14} + \frac{1}{4}$

11. Add: $\frac{1}{7} + \frac{1}{4}$

12. Add: $\frac{5}{12} + \frac{5}{8}$

13. Add:

$$\begin{array}{r} \frac{1}{2} \\ +\ \frac{9}{14} \\ \hline \end{array}$$

14. Add: $1\frac{7}{9} + 6\frac{9}{10}$

1 3

17. Add: $9\frac{1}{3} + 6\frac{1}{4} + 6\frac{1}{2}$

18. Add. Write a mixed numeral for the answer.

$$\begin{array}{r} 1\frac{1}{2} \\ + \ 3\frac{3}{5} \\ \hline \end{array}$$

19. Find the LCD: $\frac{4}{5} + \frac{4}{15} + \frac{1}{6}$

20. Find the LCD: $\frac{5}{7} + \frac{5}{21} + \frac{1}{6}$

GRE Preparation Course

Fractions: LCD and Addition

12/10/1996 | Page 1 | Form 1

[1] LCD = 24

[2] $\frac{3}{11}$

[3] $\frac{6}{11}$

[4] $3\frac{1}{5}$

[5] $1\frac{1}{5}$

[6] $5\frac{6}{13}$

[7] $9\frac{5}{8}$

[8] $14\frac{1}{2}$

[9] $1\frac{1}{3}$

[10] LCD = 28; sum = $1\frac{17}{28}$

[11] $\frac{11}{28}$

$1\frac{1}{7}$

[13] ______________________________

$8\frac{61}{90}$

[14] ______________________________

$4\frac{19}{30}$

[15] ______________________________

$6\frac{14}{15}$

[16] ______________________________

$22\frac{1}{12}$

[17] ______________________________

$5\frac{1}{10}$

[18] ______________________________

LCD = 30

[19] ______________________________

LCD = 42

[20] ______________________________

Appendix K

Example of Fractions Test

GRE Preparation Course

Fractions: TEST

12/10/1996 | Page 1 | Form 2

1. Find the LCD: $\frac{6}{7} + \frac{2}{21} + \frac{1}{6}$

2. Add: $\frac{5}{7} + \frac{1}{7}$

3. Add: $3\frac{1}{3} + 9\frac{3}{4}$

4. Subtract: $\frac{14}{17} - \frac{13}{17}$

5. Subtract: $\frac{10}{11} - \frac{1}{4}$

6. Subtract: $11\frac{1}{8} - 1\frac{6}{7}$

7. Multiply: $\frac{1}{3} \times \frac{3}{7}$

8. Evaluate and completely reduce the answer: $\frac{6}{8}$ of $\frac{24}{72}$

9. Multiply: $\frac{1}{4} \cdot 3\frac{1}{2}$

10. Divide: $\frac{2}{9} \div \frac{10}{7}$

11. Divide: $\frac{3}{7} \div 1\frac{1}{8}$

12. Find $3\frac{2}{7} \div 4\frac{1}{7}$. Give your answer as a completely reduced proper fraction or mixed number.

13. Find the quotient and completely reduce the answer: $\frac{1}{49} \div 7$

14. Insert <, >, or = to form a true statement.

    $\frac{3}{8}$ ___ 0.38

15. Write 0.9 as a fraction.

16. Write 4.15 as a reduced fraction.

17. Write as a decimal: $\frac{17}{1000}$

18. Write $\frac{7}{10}$ as a decimal.

19. Subtract and give the answer in completely reduced form:
$$\frac{-4x + 2}{x^2 - 4} - \frac{-3x}{x^2 - 4}$$

20. Subtract and give the answer in completely reduced form:
$$\frac{3}{x^2 - x - 42} - \frac{2}{x - 7}$$

GRE Preparation Course

Fractions: TEST

12/10/1996 Page 1 Form 2

[1] LCD = 42

[2] $\frac{6}{7}$

[3] $13\frac{1}{12}$

[4] $\frac{1}{17}$

[5] $\frac{29}{44}$

[6] $9\frac{15}{56}$

[7] $\frac{1}{7}$

[8] $\frac{1}{4}$

[9] $\frac{7}{8}$

[10] $\frac{7}{45}$

[11] $\frac{8}{21}$

$\frac{1}{343}$
[13] ______________________________

[14] ______________________________

$\frac{9}{10}$
[15] ______________________________

$\frac{83}{20}$
[16] ______________________________

0.017
[17] ______________________________

0.7
[18] ______________________________

$0.41\overline{6}$
[19] ______________________________

$\frac{4}{5}$
[20] ______________________________

Appendix L

List of Fluency Drills and Aims

Fractions Fluency Drills & Aims

#	Unit	Drill	Aim
1	**Fractions**	Decimals to Fractions	1:23
2		Fractions to Decimals	2:19
3		LCD and Addition	3:42
4		Subtraction	4:22
5		Multiplication	3:14
6		Division	3:08
7		Rules	1:26

Appendix M

Additional Data From GRE Preparation Courses

COMPARISON OF SPRING, SUMMER, AND FALL COURSES

Students taking the actual GRE from all three courses had higher scores on the verbal portion of the GRE on the October administration of the examination than they did on the posttest administered at the end of the course. Conversely, for the quantitative portion of the examination, students from the spring and summer semester courses performed better on the posttest than they did on the actual GRE. Only in the case of the fall semester did students perform better on the actual GRE. Combining the verbal and quantitative portions, students from the spring and summer courses performed better on the posttest and students from the fall course performed better on the actual GRE.

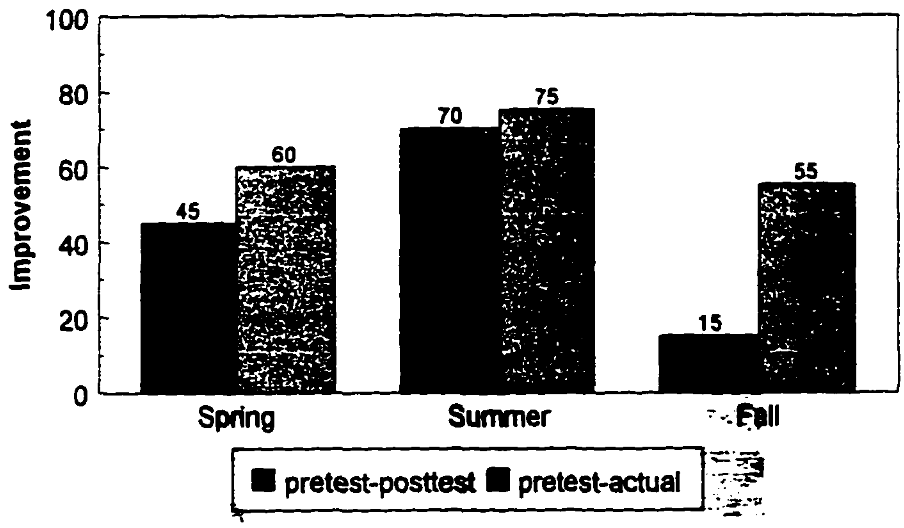


Figure __. Mean GRE-V improvement from pretest to posttest and pretest to actual GRE for all students.

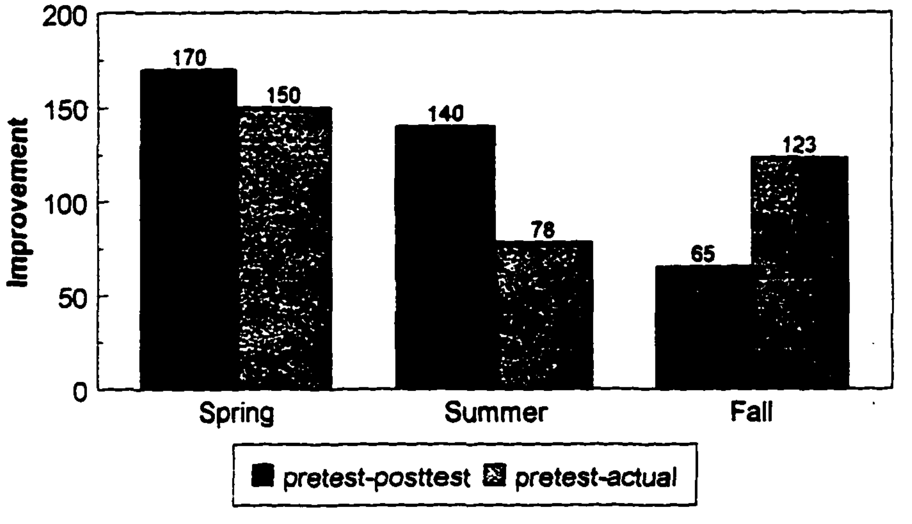


Figure __. Mean GRE-T improvement for all students taking the actual GRE.

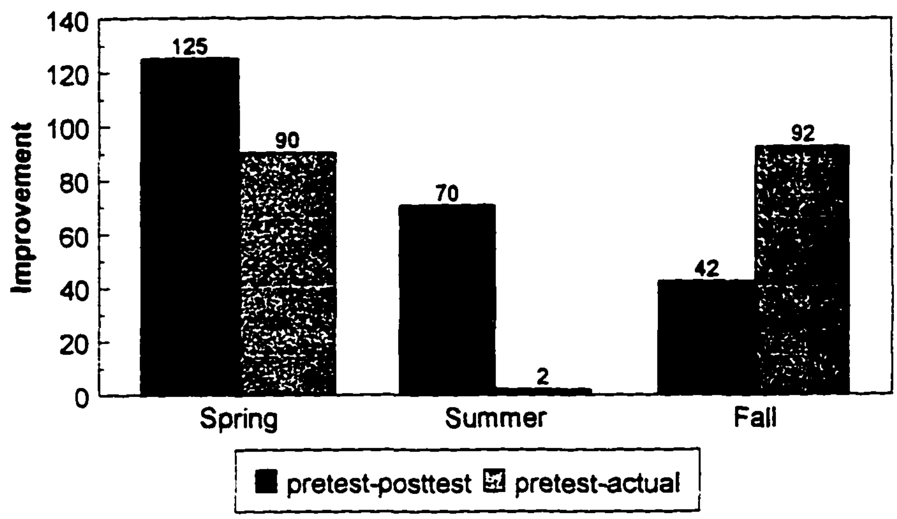


Figure __. Mean GRE-Q improvement for all students taking the actual GRE.

COMPARISON WITH 1994 GRE COURSES

Students enrolled in the series of 1994 GRE-preparation courses had mean improvements for the spring, summer and fall courses were 86, 94, and 103 points respectively. The mean improvements for the spring, summer and fall courses in 1995 were 192, 116, and 52 respectively. The mean improvements for the 1994 series of courses for those taking the actual GRE were 78 in the spring, -20 in the summer, and 68 points in the fall, while the mean improvements for the students in the 1995 courses were 150, 116, and 137.

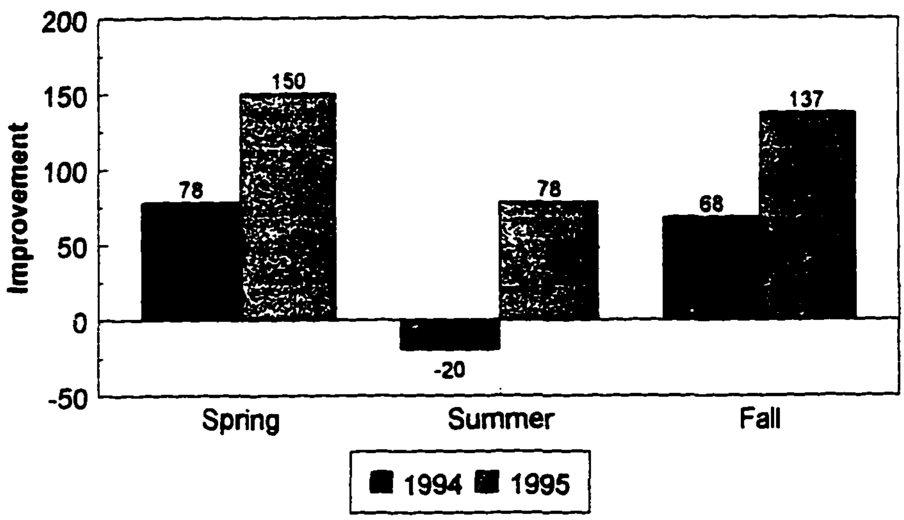


Figure __. Mean GRE-T pretest to GRE-T actual improvement for test-takers: 1994 vs. 1995

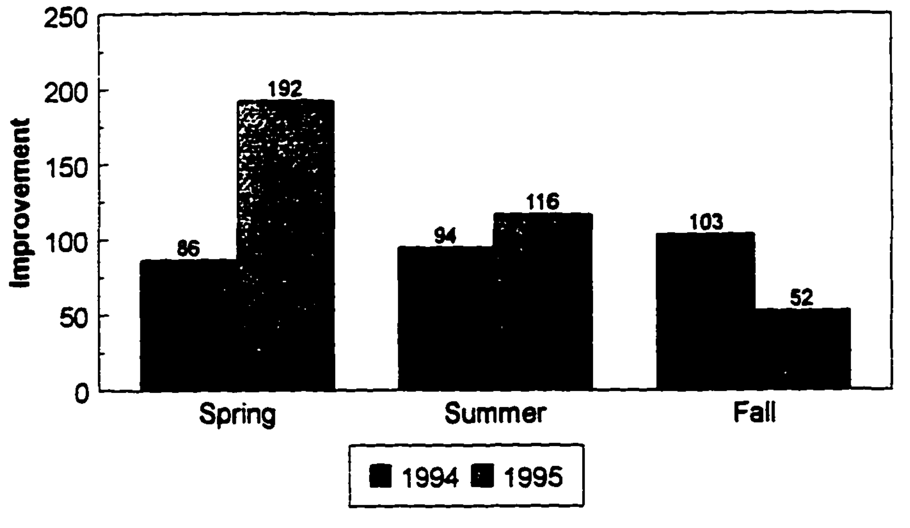


Figure __. Mean GRE-T pretest to posttest improvement: 1994 vs. 1995.

Appendix N

Human Subjects Institutional Review Board Approval

WESTERN MICHIGAN UNIVERSITY

Date: April 19. 1995

To: Vunovich. Pam

From: Richard Wright. Interim Chair Richard A. Wright

Re: Old HSIRB Project Number 94-01-09
New HSRIB Project Number 95-04-19

This letter will serve as confirmation that an extension to your research project entitled "The effects of self-study on GRE Verbal and Quantitative scores" has been granted by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now continue to implement the research as described in the original application.

You must seek reapproval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date. In addition if there are any unanticipated adverse or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: Apr. 19. 1996

xc: Richard Malott. Psych

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-3899
616 387-8293

WESTERN MICHIGAN UNIVERSITY

Date: January 26, 1994

To: Ann Goodyear-Orwat

From: M. Michele Burnette, Chair

Re: HSIRB Project Number 94-01-09

This letter will serve as confirmation that your research project entitled "The effects of self-study on GRE Verbal and Quantitative scores" has been **approved** under the exempt category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

You must seek reapproval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: January 26, 1995

xc: Malott, Psychology

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