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A Study of the Effects of Early Remediation in Prerequisite Material in a Calculus I Course

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Abstract

Success in Calculus I is almost impossible without strong algebra and trigonometry skills. However, many students arrive in Calculus I either weak or rusty in these areas. Furthermore, it is difficult for the students to improve their algebra and trigonometric skills over the course of the semester while trying to apply them to the new calculus concepts. With Calculus I being such an important gateway course into engineering fields, finding ways to address this problem seems essential to recruiting and retaining engineering students.

In this paper, the author describes an approach to early remediation in prerequisite material in a Calculus I course at a polytechnic institution. Preliminary results are presented regarding the success of this approach, including a comparison of course grades to comparable groups, student feedback, and instructor observations.

Introduction

Success in introductory mathematics courses (College Algebra, Precalculus, Calculus I, and Calculus II) is essential to success in engineering disciplines[5]. It is also widely acknowledged that more graduates in engineering and related fields are needed. For example, the Obama administration has announced a goal of increasing the number of students who receive undergraduate degrees in STEM fields by 1 million over the next decade. With this goal in mind, achieving even incremental decreases in DFW rates (the percentage of students who withdraw or receive a D or F) in introductory mathematics courses is important.

While it is generally agreed that high DFW rates in gateway mathematics courses are a significant stumbling block to increasing STEM graduates, pinpointing the reasons behind high DFW rates in these courses is not easy, partly because the reasons vary widely among institutions and students. At the author's small polytechnic institution, experience has shown that inadequate mastery of prerequisite material is a significant contributing factor. In an attempt to address this problem of poor preparation, the author undertook a program of early incentivized remediation in prerequisite material in a section of Calculus I in Fall 2012. Students were given an early exam on prerequisite material, and were given an opportunity to retake the exam if they completed various remediation activities. Students with lower scores were required to complete more remediation. Activities included completing exam corrections, doing additional homework assignments, and attending office hours.

This paper reports on the results of the incentivized remediation program conducted at the author's polytechnic university. Although the students' above-average performance cannot be decisively attributed to the remediation program, the results of the study indicate that this approach merits replication and further study.

Literature Review

There have been many programs implemented around the country to attempt to help students bridge the gap between their current knowledge in mathematics and the knowledge needed to be successful in calculus. One example is the Emerging Scholars Program, developed at the University of Texas-Austin following the ideas of Uri Treisman[2]. These workshop-style courses have been replicated in many locations around the country. They generally involve an extra day (or more) of class time per week in addition to the typical required lectures. Another common approach is to provide a bridge course prior to the beginning of the semester. Some universities have offered one-week bridge courses, such as Purdue[4]. Others, such as such as the University of Missouri-Rolla[1] and the University of Alabama[6], have offered longer bridge programs in the summer.

These programs have generally shown good results. However, they are resource-intensive, and as such they can be difficult to implement on a large scale. Note that participation in such programs generally requires students to acknowledge weakness in mathematics prior to beginning calculus; in the author's experience, many students do not possess that self-awareness.

Other programs have attempted to remediate students after their arrival in the Calculus course. One approach is to allow students who are performing poorly at mid-semester to switch into an intensive precalculus course for the second half of the semester[8]. At North Carolina State University[9], students in a Calculus course identified as at-risk early in the semester were invited to participate in a program in which they met with an academic advisor and developed an action plan for improvement.

The incentivized remediation program discussed in this paper bears strong resemblance to two previous studies. One study involved a "Success Enhancement Program" in a Physics for Engineers course at the University of Tennessee[3]. Students were able to earn back lost points on their first exam by completing various requirements based on their performance on the exam, including completing corrections, working extra problems, attending study sessions, and retaking the exam. There was no control group, so it was difficult to determine the specific effects of the program, though it generally seemed to be successful.

A more extensive program was initiated at West Virginia University[7]. Students were given an exam on Calculus I readiness during the second week of the semester. Those performing poorly on the exam were given the opportunity to either switch into a precalculus course, switch to a two-semester version of Calculus I that included extra review of algebra and trigonometry, or remain in the traditional Calculus I course with the knowledge that extra effort would be needed in order to succeed. The university also offered a variety of interventions to assist students who remained in the traditional Calculus I section, including offering optional review sessions on prerequisite material and a "grade recovery program," in which students meeting certain criteria (homework completion, class attendance, and attendance at extra study sessions) were permitted to replace their lowest exam grade with their final exam grade. There

were many other aspects of the program, and the reader is referred to their paper for a complete description of the study and the results of various aspects of the study.

The intervention discussed here had similarities to both of these programs, particularly the one at the University of Tennessee. Unlike that study, some conclusions about the success of the intervention can be drawn. The next section describes the studied intervention.

Description of the Program

A program of early incentivized remediation was tested in a section (referred to here as the "test section") of Calculus I taught by the author in Fall 2012 at Southern Polytechnic State University (SPSU). SPSU is a special-purpose institution in the University System of Georgia, with more than 5000 students enrolled. Many of the students are nontraditional. The school's mission is to offer both traditional and nontraditional students bachelors and masters degrees and continuing professional development in the sciences, engineering, engineering technology, applied liberal arts, business, and professional programs. As is typical due to the degree programs offered at SPSU, over half of the students in the test section were Engineering or Engineering Technology majors.

The course setup for the test section was typical for Calculus I courses at SPSU. Thirty-five students were enrolled in the course. The class met four days per week for 50 minutes. The format of the class was primarily lecture, with active learning activities interspersed throughout the semester. The students were given four exams during the semester and a cumulative final exam. Announced quizzes on homework problems were given approximately once per week, and unannounced homework checks, also approximately once per week, were done on the basis of completion.

During the first two class meetings of the semester, the students worked in groups on worksheets reviewing important prerequisite material. The topics for the worksheets included specific algebra and trigonometry skills that are used in a typical Calculus I course, such as addition and simplification of rational expressions, evaluation of trigonometric functions, and solving algebraic and trigonometric equations. (Worksheets are available from the author upon request.) On the third day of class, students were given an opportunity to ask questions on the worksheet. Once all questions were answered, the instructor moved on to new Calculus I content, and no more class time was explicitly devoted to review.

The students in the test section were given a test on the prerequisite material on the fifth day of class. The prerequisite test (henceforth referred to as "the test") counted for 35 (out of 100) points of Exam 1, with the remaining 65 points (covering calculus material) given a few weeks later. Students who performed very poorly on the test were advised to switch into a lower course, although no students followed the advice. All students were given an opportunity to retake the test (in a slightly modified form), provided they met certain remediation criteria. The amount of remediation required varied according to their performance on the test:

- All students wishing to retake the test were required to submit test corrections, including a complete, correct solution, a description of what mistake had been made,

and a statement of how the mistake could be avoided in the future (for example by remembering a particular algebraic rule, or by checking their work more carefully).

- Students who received fewer than 30 points (of 35) also had to complete additional practice problems similar to those that were on the worksheets from the first two class days. In order to qualify for the retest, the practice problems had to be resubmitted until at least 80 percent of the problems were completely correct.
- Students who received fewer than 25 points were also required to attend at least two hours of review in office hours with the instructor and submit a study plan for the semester. The study plan included times each week when the student planned to work on homework, attend tutoring, and attend office hours.

A handout was given explaining the expectations to the students; the handout is available upon request from the author.

Students had approximately ten days in which to complete the remediation and review for the retake of the test. It was made clear to the students that the time spent on remediation should be in addition to the time spent on new topics, since new calculus content was being covered in class, and homework checks and quizzes on the new content were proceeding as usual. Students were also advised that this opportunity to retake an exam would not be repeated later in the semester, so their future exam preparation efforts needed to be adjusted accordingly.

Students completed surveys asking for feedback on the remediation program after they took the second part of Exam 1. Survey results will be discussed in the last section.

The next section describes the results of the study. In addition to comparing student grades on the prerequisite test on the two attempts, the course outcomes for the test section are compared with those of all SPSU students in Calculus I sections taught by full-time SPSU faculty (of which the author is one). Course outcomes in the test section are also compared with those achieved by the two sections of Calculus I taught by the author in Spring 2012. It should be noted that while most aspects of the course setup remained constant between the two semesters, there was a change in homework policy that may have contributed to the differing outcomes. This is discussed further in the conclusion.

Results

Improvement between the two attempts

Of the 34 students taking the initial test on prerequisite material, twelve students elected not to retake the test. (One student was ill when the test was initially offered, so he was not part of the remediation program. His results are excluded from all of the data that follow.) Of those twelve, however, seven received a 30 or better on their initial attempt. (All point totals mentioned are out of a possible 35 points.) In addition, another two of the twelve submitted the required remediation worksheet, but did not attend office hours, and thus did not meet the criteria to retake the test. This leaves only three students who seemed to be in need of remediation, but did not complete any.

The mean increase in score on the second attempt of the test was 5.5 points. Using a paired differences test, this result is statistically significant (p-value 0.000). Table 1 below shows the improvement in scores between the two attempts. The first column reports initial scores for all 34 students who took the test. The second column indicates how many of the 34 students received at least a 30 or at least a 25 (out of 35) on either the first or the second attempt.

	Attempt 1	Combined attempts
Number of students achieving 30 or better	12 (35.3%)	20 (58.8%)
Number of students achieving 25 or better	16 (47.1%)	26 (76.5%)

Table 1: Summary of improvement between two attempts (*n*=34)

It should be stressed that the two versions of the test contained different questions (and in some cases, questions on different topics), so the increase is not due to having memorized the solutions to the first version of the test. Every attempt was made to keep the two versions of equal difficulty, although that is difficult to measure.

It is interesting to note that of the eight students who failed to ultimately achieve a 25 or better on the prerequisite test, only one achieved a grade higher than a D in the course, and he was one of the students who completed the remediation assignment but was unable to retake the test due to missing office hours.

Comparison to other Fall 2012 Calculus I sections

The table below shows the final grade breakdown for the test section of Calculus I, as well as the grade breakdown for all other Calculus I sections at SPSU taught by permanent faculty members. (The restriction to full-time faculty members is due to a historical difference between course outcomes for permanent and adjunct faculty in our department.) The "Overall GPA" below attributes four points to students achieving an A, three points to those with a B, two points to those with a C, one point to those with a D, and none to those who withdrew or received an F.

	Test section (*n*=34)		All other sections (*n*=208)	
Course grade	Number of students	Percentage of students	Number of students	Percentage of students
A	12	35%	43	21%
B	6	18%	37	18%
C	6	18%	37	18%
D	5	15%	26	13%
F	3	9%	38	18%
Withdrew	2	6%	27	13%
Overall GPA	2.44		1.84	

Table 2: Comparison of test section with other Fall 2012 Calculus I sections

The GPA improvement in the test section is statistically significant (p-value .02). Notice in particular that the proportion of students receiving a B, C, or D is relatively consistent between the two groups, but the test section received a much higher proportion of A's (p-value .03) and a much lower combined proportion of F's and W's (p-value .02).

Comparison to the author's Spring 2012 Calculus I sections

The table below shows the combined breakdown of course grades for the author's two sections of Calculus I taught in Spring 2012. For ease of reference, the grade breakdown for the test section is again included.

The GPA improvement in the test section is again significant (p-value .001). Again, there is a dramatic increase in the percentage of students achieving an A (p-value .01) and a decrease in the percentage of students receiving an F or a W (p-value .001).

	Test section (n=34)		Spring 2012 sections (n=65)	
Course grade	Number of Students	Percentage of students	Number of students	Percentage of students
A	12	35%	10	15%
B	6	18%	10	15%
C	6	18%	7	11%
D	5	15%	7	11%
F	3	9%	14	22%
Withdrew	2	6%	17	26%
Overall GPA	2.44		1.40	

Table 3: Comparison of test section with author's previous sections

Conclusions and Future Work

The data clearly indicate improved performance in the section with early incentivized remediation. However, it is not clear that all of this improvement should be attributed to the remediation program. As mentioned in the introduction, the instructor's homework policy in the course changed between Spring 2012 and Fall 2012. In Spring 2012, homework for each exam was assigned all at once, and students completing at least 75% of it earned extra credit points toward their exam. This policy was a failure; very few students completed 75% of the homework, and in fact, many students did no homework at all. As a result, in Fall 2012, the instructor began giving daily homework assignments and conducting weekly homework checks which accounted for 10% of each student's final grade. Many more students completed homework in Fall 2012, which likely had a positive impact on student outcomes.

Nonetheless, it seems that the early incentivized remediation program was responsible for at least some of the improvement. In what follows, several aspects of the program that may have been beneficial are discussed. Student comments included below were in response to the

question, "Do you feel the early exam on prerequisite material was helpful? Why or why not? Please be as specific and detailed as possible," asked on an anonymous feedback form after the second (calculus) portion of Exam 1.

First, students do arrive in Calculus I needing review in many algebra and precalculus topics. This is evidenced by the students' improvement between the first attempt on the prerequisite test and the retake. The review days at the beginning of the semester, and even the early test on the material, seems not to have been enough for the students to review sufficiently. For many students, it was only the prospect of being able to raise their poor score on the first attempt that motivated them to spend the time needed on review. There were many student comments supporting this idea, for example:

> "I think it was very helpful, because it made sure everyone had the fundamentals down. The retake made me make sure that I had learned the pre-calc material, whereas without the retake, I probably went (sic) not have spent as much time on it. I took Calc I last semester, and I had to withdraw. I think a big part of the problem was my struggle with pre-calc."

The poor outcomes for students who failed to achieve at least a 25 out of 35 on the prerequisite test also support the importance of beginning the semester with strong algebra and trigonometry skills. Future work should investigate what can be done to help the students who fail to achieve this minimum competency level even after the remediation.

Instead of spending the beginning of the semester on review, another approach to improving prerequisite skills (and the one previously employed by the instructor) is to review algebra and trigonometry skills as they are needed in the course. It did not seem that the overall time spent on calculus instruction was compromised in any way by reserving three class periods at the beginning of the semester for review, as time that would otherwise have been spent on reviewing skills as needed was saved throughout the semester. Furthermore, students seemed to appreciate the time devoted to review at the beginning.

> "I liked the prerequisite partial exam it gave more of a focus on it which allowed more time to study old material rather than shrugging it off and forgetting about it. The retake forces you to do a bunch of extra work, which was helpful in learning and understanding the material better."

Another benefit of the early test is that it gave the students an early warning of the effort needed to be successful in the course. At SPSU, there are many students who engage very little in the course before the first exam (usually three or more weeks into the semester). If they fail the first exam, it can be very difficult to recover, particularly when they have weaknesses both in prerequisite material and in the new calculus content. Giving the prerequisite test so early, and then providing them an opportunity to repair their grade with sufficient effort, allows them to adjust their approach to the course before it is too late. Several students commented on this.

> "The early exam material helped me in that it showed how much I didn't know and forgot. It also showed how badly I need practice and to study."

> "Yes, [the exam] helped me realize that I am quite dumb. To be specific I felt before that re-req exam I was on par with everyone math wise, however as I soon discovered I was indeed no where near on par with my peers."

Requiring office hours as part of the remediation may have been a key component of the program's success. Although there was no formal data collected, the author observed a significant increase in participation in office hours in Fall 2012 as compared with Spring 2012. Several of the students who attended the office hours required for retaking the test continued to attend office hours regularly throughout the semester. While there is no way to tell whether they would have done so without the early incentive, it is a feature of the program meriting further study.

Overall, this program of early incentivized remediation has shown significant promise. The author plans to replicate the program in Calculus I in the future, and the program also merits study both at other levels and at other institutions. There should also be further exploration of which topics should be included in the early review. Student comments have already informed several changes for the next time the program is offered, including more trigonometry and generally more examples of all types. The program will be expanded by the author to Calculus II in 2013, focusing the early review there on the fundamentals of transcendental functions and basic differentiation and integration rules.

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