Self-Paced Problem Solving Versus the Traditional Lecture: An Experiment in Precalculus

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Abstract

Precalculus is a very important class in preparing mathematics and science majors for their coursework in college. At Bloomsburg University, we conducted an experiment in teaching Precalculus that compared a problem-oriented, self-paced approach versus the traditional lecture. We were motivated by the fact that students in Precalculus have a wide variety of mathematical backgrounds. In this research report, we describe the experiment and give results, which consist of a common final exam for the experimental and control courses as well as retention rates into the calculus sequence.

Precalculus at Bloomsburg University serves many purposes. Starting in 2001, every incoming math and science major must take a placement exam in mathematics, so Precalculus is for many a stepping-stone into the calculus sequence, while for others it is a way to fulfill the obligatory math requirement. The traditional lecture format for this class seems to fail many of the students. Some require a quick review of certain topics, while others need a more in depth analysis of the basic concepts, and the only people who are truly suited for the class are those somewhere in between. Is there a way to meet the needs of all the enrolled students, making the class more accessible to the audience in general? We also considered the fact that most students in the course have seen many of the topics covered at some point in their lives; for some it has only been a year, while for others it might have been a decade since they last saw the material. Could we use this buried knowledge to our advantage, perhaps by offering a self-paced/web-based course? We looked at other mathematics programs, and in particular we noticed the success of the Math Emporium at Virginia Tech. The Math Emporium is a well-equipped laboratory in which students complete courses at their own pace, with guidance from faculty and other students (Trulove, 1999). So we decided to run an experiment to see if it would be

possible for Bloomsburg University students to learn mathematics successfully in this type of environment.

Method

During the 2001-02 academic year, we conducted an experiment comparing the traditional lecture-based precalculus class with a self-paced/web-based class. In the fall, we offered three traditional and two experimental sections, while in the spring we had one of each type. Students were randomly assigned to a section, unaware of the type of course they would have. All sections used **Precalculus with Limits** by Lial, Hornsby, and Schneider (2001). Grades were based on homework, exams, and a final that was common to all sections. Although the instructors had some leeway in the homework portion of the grade, each class had three exams totaling 60% of the grade and a final that was worth 25%. The lecture-based sections were used as our control group for this study.

The experimental sections used the software MyMathLab and MathXL (Addison-Wesley, Boston, MA). This software allows students to work through tutorial exercises, view mini-lectures, try practice exams, etc. At the beginning of the semester students were informed of the material that needed to be covered, but for the most part they were allowed to go through the material at their own pace, without lectures. During the class, the instructor and a student assistant walked around the room to answer questions as they arose.

For the self-paced classes, students had three opportunities at each of the three examinations. We hoped that this would encourage the students to take the exams early so that they could figure out what they needed to learn. In fact, we required that the students retake an exam unless they had taken it three times or received a minimum score of 80%. The final exam, however, was common to all the sections and was only given once to each student.

We considered two criteria in assessing the performance of students and success of the self-paced class. First was the performance of each class on the common final. Each semester, we calculated the average final exam score of all students in the self-paced course and the average final exam score of all students in the lecture-based sections. We tested these averages for a statistically significant difference. Secondly, and in some ways more importantly, we tracked the retention rate of those students needing to continue into the calculus sequence: what percentage of students were retained in the calculus sequence and did they succeed in those classes? Before we discuss the first-year results of this experiment, we will describe briefly what happened each semester.

Fall

In the fall of 2001, Drs. Lister and Loomis taught the lecture classes while Dr. Polhill had the challenge of being the first to teach the experimental section. Problems developed with the self-paced class before the semester began. In teaching any course that relies primarily on computers, there will usually be some complications and this was no exception. Although the software can be accessed through Netscape, our university had the wrong version and the computers did not have Explorer loaded. Getting the lab properly equipped put the class about a week behind. Even after the software was properly installed, the channels were very slow so that some applications were difficult to use while others could not even be accessed.

In the environment of the self-paced class, we found that some students thrived. These students were able to learn what they needed without spending weeks on topics they already knew. For other students and for the class in general, however, more problems arose.

The first problem was the fact that there were no absolute deadlines for the class. Although Dr. Polhill gave strongly recommended deadlines for each exam, many students began studying the last two chapters with 2 weeks or less remaining before the final. The last two chapters cover trigonometry, which is quite difficult to learn in just 2 weeks. This caused many students to be at a distinct disadvantage when it came time for the final exam.

Another disadvantage these students faced was the fact that Dr. Polhill used the TestGen-EQ software that accompanied the text to create the various are exactly alike, so cheating is much less of a problem. However, these tests have a significantly different format from the common final exam. Students who became accustomed to this format found the final extremely challenging.

About 5 weeks into the semester, due to overwhelming demand from the students, Dr. Polhill began giving mini-lectures on select topics. Each of these lectures covered about half a class period. The problem was that about a third of those attending class relied entirely on these mini-lectures, which were not meant to cover everything necessary for a student to succeed.

Spring

In the spring different students were randomly assigned to the self-paced and lecture sections. To avoid bias because of instructor, Drs. Lister and Polhill exchanged roles. Dr. Polhill taught the lecture section while Dr. Lister took over the self-paced class. Dr. Lister made significant modifications to the course to correct the problems from the previous semester.

First, to avoid having students attempt to learn trigonometry in 2 weeks, firm exam deadlines were set. This forced people to stay on track, but still allowing some freedom to cover certain topics quickly and others in more detail. Secondly, to avoid

having to give mini-lectures, Dr. Lister prepared detailed “lecture” notes. These essentially are the notes her students would have had if they were taking a traditional lecture class. This entailed an enormous amount of work but has the advantage that once completed, these notes could be used in subsequent semesters. Finally, Dr. Lister wrote her own exams. For each exam, she made three versions, warning students that they were hurting themselves if they shared the exams with others, since their averages would be lower than those with whom they shared information. Hence they would hurt their chance for any scale in the grades. These adjustments seemed to solve many of the problems from the previous semester, but a new one arose. For some reason, many students just disappeared from the self-paced class. They neither withdrew, nor did they do the work. In fact 21.4% fell into this category, a problem, which if this method is to succeed, must be addressed.

Results

As noted earlier, we are assessing the success or failure of the experiment in two ways. The first is a comparison of the final exam average of the students in the lecture courses versus the self-paced courses. From our experience in the fall semester, we expected there to be a statistically significant difference between the two types of classes for the reasons noted above, namely computer glitches, lack of firm deadlines, and exams with a different format. The results strongly supported our fears.

In Table 1 we give the data from the fall 2001 final exam. It shows the average final exam score with standard deviation for each mode of instruction. An independent t test indicated that the final exam scores of the lecture group were significantly higher than the final exam scores of the self-paced group, $t(116) = 4.892$, $p < .0005$.

Table 1

Final Exam Scores-Fall 2001

	Method of Instruction	
Class Statistics	Lecture	Self-Paced
Number of Students	77	56
Average Score (Percent)	61.66	46.35
Standard Deviation (Percent)	17.57	18.00

We expected the scores to be much closer in the spring semester. We hoped that the changes in the experimental section would lead to some improvement, but we had no way of knowing until the finals were taken. The results in Table 2 show that the changes did help in the final performance, which indicates that the web-based sections have promise.

Table 2

Final Exam Scores-Spring 2002

	Method of Instruction	
Class Statistics	Lecture	Self-Paced
Number of Students	33	23
Average Score (Percent)	60.20	61.02
Standard Deviation (Percent)	17.56	19.07

The t-test demonstrates that there was no significant difference between the final exam scores of the lecture and self-paced sections, $t(44) = 0.163$. In fact, the self-paced average was slightly higher than the lecture section average. So we seem to have made significant progress in improving our self-paced course, or at least we are preparing the students better for the final examination.

The second method of comparison was in the retention rate of our students through calculus and beyond. This aspect of the assessment was very important, since we not only want to retain mathematics majors, but all science majors as well. Table 3 shows the percentage of students that progressed from the fall 2001 Precalculus self-paced and lecture sections into Calculus 1 and Calculus 2.

Table 3

Retention of Students from Fall 2001 Sections of Precalculus

		Method of Instruction			
Class Statistics		Lecture		Self-Paced	
		N	%	N	%
Calculus 1	Enrolled	31/48	64.6	25/35	71.4
	Passed	27/31	87.1	20/25	80.0
Calculus 2	Enrolled	13/48	27.1	16/35	45.7
	Passed	11/13	84.6	12/16	75.0

The enrollment data is based on the original number of students in calculus-requiring majors in each of the precalculus sections. We also include the success rate of the students in these courses, success being defined as passing. The passing rates are based on the number of students taking Calculus 1 or 2. We reiterate that the data in the chart is based on the percentage of students that, upon enrollment in the Precalculus course, had

majors that required them to take Calculus 1 and 2. In the discussion section we will include some information on students whose majors did not require calculus. The data indicates that both classes are retaining a reasonable number of students into the calculus sequence and most of these students are passing Calculus 1.

For the spring 2002 students in Precalculus, 72.7% from the lecture and 46.7% from the web-based class went on to Calculus 1. Again these percentages are based on all the students that had majors requiring calculus. We also note that 20% of the students from the self-paced course who needed Calculus fell into what we call the lost student category. This consists of all students who stop coming to the class and never take one or more of the three semester exams. We will continue to track these students through the calculus sequence.

In terms of retention, the self-paced course seems to be doing fairly well, particularly with those students who enrolled in the problematic fall 2001 course. This is encouraging, and we will continue to track these students while continuing to make improvements in the course. Somehow we need to encourage students to persevere through the challenges that the self-motivated course presents.

Discussion

We are no longer performing a controlled experiment. Instead, the formerly experimental sections have developed into a motivated self-paced course. We feel strongly that the self-paced course can succeed and will continue to offer the class throughout the 2002-2003 academic year and probably beyond.

In the results section, we discussed retention of students in majors needing calculus. With respect to students in majors not requiring calculus, 10% (3 out of 30) of the students in the fall 2001 self-paced sections and 2.4% (1 out of 41) of the students in

the fall 2001 lecture sections went on to Calculus 1 despite not needing it for their major. The three students from the self-paced course passed Calculus 1.

While we have made progress, improvements must be made, and in particular we must solve the problem of lost students. Recall these are the students that stop showing up to class for one reason or another. One primary factor in the disappearance of these students is that many of those enrolled in the class are first-year students. Many are on their own for the first time and giving them so much freedom in learning can be dangerous. It is very easy for immature students to set aside the work for a course such as this, causing them to fall behind quickly. To warn students of this pitfall, the instructor must stress that staying on track is very important, as is attendance. In fact, during the spring semester, only one person failed the self-paced course among those who attended regularly (as opposed to three from the lecture section). Stressing the importance of keeping on track seems to have had some impact on the attendance in the class for the current semester, but it is too early to tell if these efforts will succeed.

Due to all of the challenges we face with the self-paced style, it would be easy to revert back to offering only the lecture method. However, we feel there is much to gain. For example, an unexpected bonus of the special sections is that the students learn early the important study and time management skills necessary to succeed in college. The instructors who have had these students in calculus have indicated that there was a definite difference in mathematical maturity between those students from the self-paced course and those from the traditional sections. Students in the self-paced sections have the opportunity to take control of their learning, which is a very valuable asset.

An additional benefit of the self-paced course is the fact that students use technology to a much greater extent than with the lecture course. This is a great benefit considering the current standards set by the National Council of Teachers of

Mathematics. In fact, many of the students in our course are secondary education/mathematics majors.

At this point, we have several options to consider for this course beyond the 2002-03 academic year. We could drop the self-paced course entirely, offer it as a preparatory course during the summer to incoming students, expand it into a distance learning class, or continue to offer it as is.

If you have thoughts of offering such a course we recommend the following:

1. Set up all labs with necessary software well in advance, and test them out on a handful of students.
2. Have all course materials prepared in advance and available from day one.
3. If possible, have a teaching assistant in class to help the instructor answer student questions.
4. Make firm deadlines to give the students guidance.
5. Last but most importantly, be prepared to exhort the students constantly.

References

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