CALCULUS PREREQUISITE DIAGNOSTIC QUIZZES AND TUTORIALS WITH THOMSONNOW

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Introduction

Algebra is a key ingredient of "the language of calculus". Trying to learn calculus with an inadequate algebra background is as hopeless as trying to study works of foreign literature without properly learning the language it is written in. Yet, sadly, the former is precisely what we find more and more of our calculus students attempting to do. Those students tend to "limp through" calculus, along the way suffering from many algebra- and trigonometry-related setbacks. Frequently, the result is either failing the course (sometimes repeatedly), or passing it with a substantially lower grade than the student would be otherwise capable of attaining with the proper prerequisites in place.

There are numerous possible reasons why prerequisite deficiencies are so widespread, however, tackling those issues is outside of the scope of this undertaking. Moreover, it is not an option to "address" the problem by making each student who lacks proper prerequisites take a precalculus (or even algebra) course instead of calculus. This is partially due to political considerations (e.g., articulation agreements), but mostly due to the sheer magnitude of the problem (see Fig.2).

Faculty at other institutions have attempted tackling similar problems in various ways. The bibliography at the end of this article includes only a small sample of relevant papers. A number of efforts focus mostly on "gateway" assessment of calculus skills, with some precalculus skills included (e.g. [3,4]), but there are some attempts [1,2,5] to couple such assessments with remedial learning opportunities for students.

This is the direction we shall follow here in that our main objective is creating a mechanism to

A. identify prerequisite areas in which individual calculus students are deficient and
B. provide students with opportunities to address their deficiencies early in the course.

In both A and B, our key concern will be to

C. avoid uniform "one size fits all" assignments, instead attempting to target the specific areas relevant to the individual student.

In Section 1, we show how a diagnostic quiz is used to achieve objective A. Two sections that follow are devoted to accomplishing the (more challenging) objectives B and C using online tutorials and subsequent quiz attempts.

1. Prerequisite Diagnostic Quiz (PDQ) - Initial Attempt

During the first week of classes, all students enrolled in the pilot sections of calculus are given a paper-and-pencil diagnostic quiz. The quiz contains questions covering specific prerequisite areas of particular relevance to the course. For example, students in Calculus II are tested on the following areas (algebra, trigonometry, and Calculus I topics):

PDQ areas in both Calculus I and Calculus II		Calculus II only
A - Exponents and Radicals	F - Functions	K - Limits
B - Algebraic Expressions	G - Polynomial Division	L - Derivatives
C - Fractional Expressions	H - Logarithmic Functions	M - Integrals
D - Equations and Inequalities	I - Trigonometry	
E - Lines and Circles	J - Trigonometric Identities	

Some areas are represented by two or three questions, while others have only one. Here are a few samples:

A question in area "D"	A question in area "F"	A question in area "I"
Solve the inequality $\|2x-3\|<4$.	Let $f(x)=2x-3$ and $g(x)=\sqrt{x}$. Find $(g\circ f)(14)$.	Find the value of $\cos\frac{17\pi}{6}$.

While most questions included are exceedingly simple, we demand nothing less than mastery of them. To receive a passing score in a given area, the student must correctly answer all questions within that area (no partial credit is given). Otherwise, the student is identified as having at least some deficiency in that area, and will be given an opportunity to correct it, as discussed in Sections 2 and 3.

2. Online Tutorials

For each area the student failed on the initial PDQ attempt, he or she is asked complete an online tutorial, which contains a number (usually 5 to 15) of questions. These tutorials are based on the ThomsonNOW (formerly iLrn) environment, which enables the student to

- enter their answers using proper mathematical notation, using a proprietary, but well-designed interface (we conduct a brief session to get the students accustomed to that interface, but it appears that most students would find it easy to use even without such a session),
- request a hint (or hints) for a question,
- ask the tutorial to break a question up into individual steps,
- see the question answered completely, then be given a similar question with different numbers,
- see the immediate feedback (right/wrong) to the responses given.

Currently, most major publishers offer similar systems. However, it made most sense for our Department to use a system offered by Thomson, the publishers of calculus and precalculus textbooks we use. The key advantage offered by this arrangement was that we were able to include publisher's precalculus modules in tutorials set up for calculus students. In fact, we have assembled some of these modules into online "summaries" for

the first ten areas. Students were encouraged to read the summary screens prior to entering the interactive part of the tutorial.

In order to complete an online tutorial assigned to them, students had to answer 100% of the questions correctly. This is reasonable, as the tutorial provides the students with extensive guidance to help them reach that goal.

3. Prerequisite Diagnostic Quiz (PDQ) - Second and Third Attempt

On the second PDQ attempt, each student is asked to answer questions only in those areas they failed on the initial attempt. We used a database to print out a customized test for each student. If a student has still not passed certain areas on that attempt, then he or she has a final chance to do so on the third attempt of PDQ.

4. Grading System

When this approach was first tried in Summer 2005, we adopted the following scheme

a. Passing an area on the first PDQ attempt gives the student the maximum score of 10 points for that area.
b. Failing an area on the first attempt results in a score of 0. Five of those missing points are re-captured by completing the online quiz, and the other five by passing the second or third PDQ attempt. Partial credit was available on the third attempt if only some questions were answered correctly in a multi-question area.
c. The resulting score counted as a test grade (scaled to 100 points).
d. If the instructor has determined that a student made a sincere effort working on all the PDQ attempts and online quizzes, then the score is dropped, if doing so improves student's grade.

In Fall 2005, part c was changed in that we started counting the resulting score as a double lab grade, rather than a test. This was motivated by a desire to continue to provide students with some motivation to complete the assignments without excessively affecting their grade in a direct fashion. (While in Summer'05 it contributed about 17% to the grade, in Fall'05 this contribution went down to about 7%).

In Spring 2006, we amended part b by no longer including the online quiz score in the total - instead, attempts 2 and 3 were worth up to 10 points. (However, completing all assigned online quizzes continues to be required to benefit from part d). There were two reasons for doing this. Firstly, we wanted to see the extent to which a decreased emphasis on the online quizzes in the grading scheme would affect students' completion of them. Secondly, Spring 2006 marked the first time that the pilot was extended beyond sections taught by the author, so we attempted to lessen the burden on the instructor associated with keeping track of the various grade ingredients.

The key principles of the grading system were

- giving a student a sufficient incentive to encourage participation, without excessively affecting the course grade and
- avoiding punishing students with very weak prerequisites, as long as they make a real effort to help themselves overcome their deficiencies.

Each student, even with substantial weakness, could potentially earn a perfect score on these assignments. While for students with good prerequisite skills this can be a relatively "easy" grade, **students with numerous deficiencies have to work much harder for the same grade**.

5. Outcomes

Figures 1 and 2 include some data based on administering the assessments described to the 96 students enrolled in three sections of Calculus II taught by the author from Summer 2005 to Spring 2006 (the sections taught by other instructors in Spring 2006 are not included). Based on the data, it appears that

- there is a wide diversity among students with respect to their areas of deficiency;
- every one among the 96 students tested was deficient in two or more areas on the first attempt; the vast majority exhibited initial deficiency in most areas;
- the vast majority of the students have shown dramatic improvement on their subsequent attempts; we have additional data (not presented here) that shows the participation in the online tutorials and quizzes was strongly correlated to the student passing the area.

Figure 1. Percentage of students passing individual areas on attempts 1, 2, and 3.

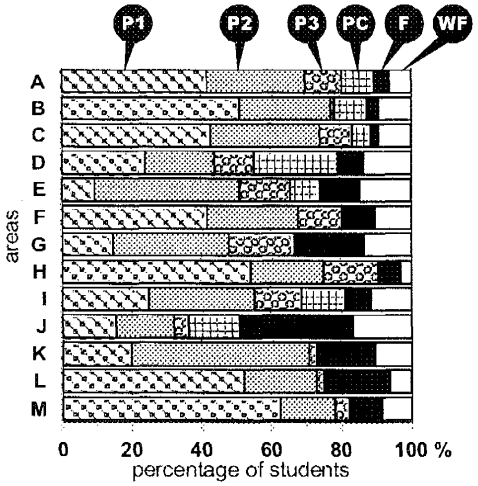
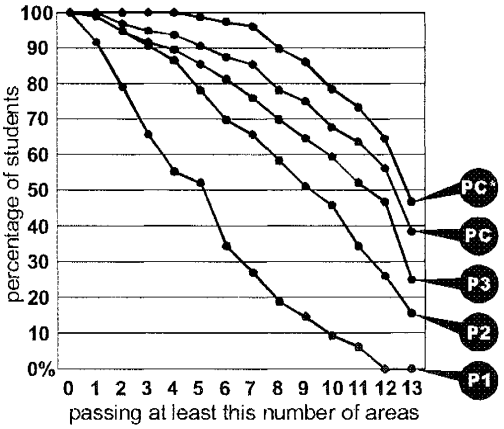


Figure 2. Percentage of students passing at least the given number of areas.



P1 Passed the 1st attempt
P2 Passed the 2nd attempt
P3 Passed the 3rd attempt
PC Partial Credit on 3rd attempt
F Failed the 3rd attempt
WF Missed the 3rd attempt
PC* Partial credit on 3rd attempt - these percentages exclude students who missed the 3rd attempt

Student response to the quizzes and tutorials described here has been very positive. At the end of the Summer and Fall 2005 sections, we asked students to complete opinion surveys. One of the questions was:

Overall, did you find that Prerequisite Diagnostic Quiz and WebQuizzes help you identify and overcome deficiencies in your algebra, trigonometry, and Calculus I background?

Of the 34 students who responded to surveys

- 59% (20 students) answered "They helped a lot"
- 32% (11 students) answered "They helped somewhat"
- 3% (1 student) answered "They did not help" and
- 6% (2 students) had no opinion.

6. Conclusions

A lot of our approach is traditional (paper and pencil), but we also rely on technology, in particular the web-based tutorials and databases. One may ask: "why bother with all this technology if a similar outcome could be accomplished by assigning, say, a couple of hundred algebra homework problems to every student in a calculus class?"

Based on our experience, this would not work.

- Some of the better prepared students would probably complete such an assignment. However, in their case, most of this work would be a complete waste of time, as their algebra is generally OK, with only a few "rough spots" that need polishing up. They would have every right to hate this kind of "busywork".
- The students with weaker backgrounds would most likely give up after trying a few problems, having found that they need to go back and study a lot of this material. The very students who need to participate the most, are least likely to do so.

While assigning uniform tasks (homework, tests, etc.) to the entire class is often appropriate with respect to new material that every student in class is expected to learn, we do not believe it to be an effective way to address prerequisite deficiencies. Once again, the key feature of our approach is that the **additional work assigned to a student targets the areas relevant to that student**.

References

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5. Sisson P. "Integrating Calculus and Algebra to the Benefit of Both" in Proceedings of the 10th ICTCM, Addison Wesley, 1998, pp. 427-431.