STUDENT CHARACTERISTICS THAT HELP PREDICT SUCCESS IN CALCULUS: RESULTS FROM A SUMMER PRECALCULUS PROGRAM

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College mathematics is often considered to be a gatekeeper for students pursuing a degree in almost any field. More specifically, calculus is often the gatekeeper for students pursuing STEM degrees and careers. At Texas A&M University (TAMU), students who wish to study engineering must complete or be concurrently enrolled in calculus in order to take the first engineering course. Historically, TAMU students, like others across the United States, often have difficulty successfully completing the calculus sequence needed for their majors (Bressoud, Carlson, Mesa, & Rasmussen, 2013; Hensel & Hamrick, 2012; Pyzdrowski, Sun, Curtis, Miller, Winn, & Hensel, 2012). Additionally, a strong predictor of persistence in engineering is extent of success in the first year of college calculus (Minichiello & Hailey, 2013). In fact, success in mathematics increases student motivation for further success (Halcrow & Dunnigan, 2012). In order to provide additional support for students to begin the calculus sequence the first semester of enrollment and to increase the achievement level, the Department of Mathematics at Texas A&M University, through a grant from National Science Foundation (NSF – DUE 856767), created a summer precalculus intervention. The Mathematics Placement Exam (MPE) was an important predictor of success in engineering calculus at TAMU, and students who participated in a summer precalculus program in addition to taking the precalculus course were more successful than students who did one or the other (Nite, 2012).

Program Description

The six-week summer PPP included several components. There was an online textbook, nearly 80 instructional videos with examples explained and worked, 50 online problem sets, and online chapter quizzes. There were four modules for students to master, with progress bars to illustrate their movement toward completion. Students were also required to spend a total of 30 hours with an online tutor in an environment that allowed them to communicate with each other and the tutor through VOIP. The online environment allowed the tutor to work problems on a whiteboard and explain them to students, to put students into small groups to work together on a whiteboard in online breakout rooms, and save the student work to discuss with the whole group when the breakout sessions ended.

Students worked at their own pace through the online problems and quizzes, but online sessions with the tutor were slated to cover specific topics in progression through the course. Tutors were given powerpoints and practice sets to be used with the students in the online sessions. Students worked through the materials in the two or three major categories for which their MPE scores showed the greatest weaknesses. The four major categories were (1) Graphs and Functions; (2) Factoring and Solving Equations and Inequalities; (3) Algebraic Fractions, Exponents, and Radicals; and (4) Trigonometry.

Methodology

All students who declared STEM majors were required to complete the Mathematics Placement Exam (MPE). Students and their parents were sent information and reminders to take the MPE as early as possible. If they answered at least 22 out of 33 questions correctly, they were allowed to register for calculus. Only in the last two years were they blocked from registering for calculus based on the MPE score; previously they were advised to take precalculus if they scored below 22. If students scored at least 15, but less than 22, they were offered the opportunity to participate in the six-week summer Personalized Precalculus Program (PPP). Students who answered less than 15 questions correctly were advised to take either precalculus or college algebra. Students were allowed to retake the exam after 30 days for a second opportunity to score at least 22 and register for calculus. Sample MPE problems were available on the website (https://mathassessment.tamu.edu/).

Students who participated in the PPP were grouped into cohorts of about 20 students each and assigned to a tutor. They were given weekly surveys to ascertain their confidence about their mathematics background, their study habits, and their expectations of the demands of a college calculus course. When students successfully completed the PPP, they retook the MPE. If they reached the cut score of 22, they were allowed to register for calculus for the fall semester. Grades were collected at the end of the semester, and correlations were calculated.

Results

Approximately 100 students participated, to some degree, in the PPP in summer 2013. The average increase in MPE scores for those who filled out survey information was 8 points. Surveys revealed that students thought the program was beneficial, they would do it again, and they would recommend it to others. They were very complimentary of the online tutors. The correlation between the MPE scores and the Calculus I grade was 0.36. It is highly possible that a better correlation would be shown if more delineation in grades were available. Number grades were not available, only letter grades of A, B, C, D, or F were given. The difference between numbers close to the letter grade cutoff (e.g., 88 and 91) is not well represented with the letter grade limitation.

Surveys were administered to students to search out factors besides the MPE score that might be indicators of success in calculus. The surveys revealed some of students' perceived strengths and weaknesses in trigonometry. In addition, expectations for college calculus and study habits and strategies were discovered through the surveys given over the six-week period. Two-thirds of students surveyed admitted that they spent less than one hour studying mathematics outside class time in high school. Adding the in-class time of an estimated five hours per week, the total time spent on mathematics in one week was six hours. In the PPP students were expected to spend six hours a week with the online tutor as well as working on the online problems and quizzes. Possibly the intensity of the summer PPP helped students experience for a short time the intensity of a college mathematics course.

The trigonometry surveys showed that students believed they were weak in solving trigonometric equations and applying trigonometric identities (see Table 1). Often in high school classes in Texas, students gain experience in both geometry and precalculus courses in finding unknown sides and/or angles in non-right triangles, but relative little time is spent in working with trigonometric identities through proofs and solving problems. Special right triangles (e.g., 45-45-90, 30-60-90, and Pythagorean triples) are generally addressed in high school geometry in Texas, and the survey revealed that students were more confident in their abilities to solve related problems in those areas than problems involving trigonometric identities (see Table 2). Not only are some topics from geometry reviewed in precalculus courses, but not all students entering TAMU have a precalculus background. It is expected that engineering students would have a strong background, but the 10% rule, requiring public universities to admit students who graduate high school in the top 10% allowed students without mathematics courses above Algebra 2 to gain admittance.

Table 1.
Trigonometry Ability Survey Results

Question	finding unknown sides and/or angles in non-right triangles.	solving trigonometric equations	applying trigonometric identities
In trigonometry, I believe I am best at	41	3	4
In trigonometry, I believe I need the most improvement in	11	17	20

Table 2.
Trigonometry Properties and Identities Survey Results

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I have memorized properties, including trigonometric values, for common triangles, e.g., 3-4-5 triangles, right triangles with a 45-degree angle, or right triangles with a 30-degree angle and can apply my knowledge in solving problems.	4	36	0	8	0
I have memorized common trigonometric identities (e.g., $\tan^2 + 1 = \sec^2$) and can use them to prove trigonometric identities and solve trigonometric equations.	0	20	0	24	4

Overwhelmingly, the students surveyed memorized how the teacher showed them to do specific types of problems and then applied them. The result is that they often do not know how to problem-solve, to work a problem different from what they have seen before. They understand they have to practice in college, although they haven't had to practice before. Clearly they know college is going to be different from what they have done in high school. They seem to realize there will not be just a lot of problems like they have seen before. In Table 3, the first column gives the past tense of the question, referring back to the high school experience. However, in the actual survey, the question about college expectations was written in future tense. For example, instead of "I read the textbook and used what I learned…" the statement said, "I will read the textbook and use what I learn…." According to their survey answers, students intend to take advantage of all the tutoring and help sessions offered. In the help sessions, students ask for help on individual problems, and often they do not work the problems themselves. In the week-in-review sessions, an instructor reviews briefly the week's concepts and works example problems. Again, often students do not work the problems themselves but just watch the instructor work them and think they will be able to do them on the exam. In reality, in the past, relatively few students at TAMU take advantage of all the resources offered to them except in the last few days or week before the exam. Only 8 out of 32 students surveyed believed they would use the strategy that involved reviewing just a couple of days before exams.

Table 3.
Learning Strategies Survey Results

Strategies	Which of the following most accurately describes how you learned to solve mathematics problems in high school?	Which of the following most accurately describes how you expect to master calculus in college?
I read the textbook and used what I learned to solve exam problems.	7	0
I found a small number of general principles, learned them well, and applied these principles to solve all of the exam problems.	11	13
I worked in a study group where we taught each other to solve different types of problems.	2	11
I memorized how the teacher showed us how to do specific types of problems and then applied these approaches to similar problems on the exams.	27	5
I worked a large number of homework problems on a regular basis, and then practice enabled me to solve the exam.	0	14

Table 4.
College Calculus Study Survey Results

Strategies	I will take advantage of all the tutoring and help sessions offered.	I will go to class, listen to the lectures, and review course materials 24-48 hours before the exams.	I will do homework problems on a regular basis (3-4 times a week) by myself.
Which of the following most accurately describes how you will study calculus in college?	20	8	12

The survey results about the type of work students prefer is interesting in that the vast majority preferred work that they feel confident that they can do well (see Table 5). They prefer not to be challenged. Students surveyed preferred having clearly specified procedures. The question did not say "clearly specified expectations' but students may not have realized the difference in terms. Of course they need to know what they are expected to do, but "clearly specified procedures" means they know step-by-step-by-step exactly what to do. In engineering they are going to have to do problems for which they do not have step-by-step procedures as they learn to solve real-world problems that may be new and different from anything done previously.

Table 5.
Work Preferences Survey Results

Preference	Always or almost always true of me	Often true of me	Sometimes true of me	Never or almost never true of me
I prefer work I know I can do well over work that stretches my abilities.	10	16	11	2
I prefer working on projects with clearly specified procedures.	14	12	13	0

In the first week of the PPP, one question asked, "To be successful in calculus at Texas A&M University, I think I will need to spend the following amount of time per week studying mathematics outside of class." Choices ranged from "less than 30 minutes" to "greater than 120 minutes." Students who earned an A or B in calculus had chosen the high amounts of time. Then, beginning in the second week of the PPP, students were asked how much time they spent on the PPP that week. Answer choices ranged from "less than 6 hours" to "more than 11 hours." Again, students who earned A or B in calculus had indicated that they spent 10 or more hours on the PPP that week.

Discussion

The surveys revealed information about the students' study habits and expectations that might have been suspected, but not confirmed. Students realized that the strategies for success in college calculus would likely be different from the strategies they used in high school mathematics. Students who earned A or B in calculus had expected to spend considerable time studying outside of class, and they spent more hours working on the PPP.

For Summer 2014, the PPP will be shortened to three weeks, but students will still be expected to spend 30 hours online with the tutor. The program content will be shortened

some, but mainly the content will be condensed into a short time. The expectation is that students will like the shorter time commitment in terms of days, although the PPP will be more intense. Surveys indicated that students need some instruction about effective study habits for college calculus and encouragement to follow the strategies they identified that they plan to use. There is a lot of support in terms of resources such as free help sessions, week-in-review, and online practice problems. However, students would benefit from instruction and encouragement in establishing good study habits for college.

Beginning in Summer 2014, additional options will be available. Students who score 22 or slightly above are still at risk, and they will be offered the opportunity to participate in a one-week bridge program to strengthen their trigonometry skills and introduce them to vectors and parametric equations. Surveys will be administered to students in the PPP and bridge program to continue collecting data about student success factors for calculus.

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