PRIMES: 
Placement, Remediation, Intervention, 
Monitoring and Enrichment for Students

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1 Background:

For almost two decades, the Mathematics Department at Texas A&M has been involved in a series of National Science Foundation (NSF) Science, Technology and Mathematics Talent Extension Program (STEP) grants to increase retention rates in the Science, Technology, Engineering and Mathematics (STEM) disciplines, specifically those disciplines requiring the Engineering Mathematics sequence (Calculus I, II, III and Differential Equations).

To achieve this goal, the department constructed a multi-faceted process that provides students in the Engineering Mathematics sequence multiple opportunities to improve their mathematical knowledge. A variety of approaches have been implemented, including integrated curriculum, online resources, project based curriculum, “flipped” instruction, etc.

This report describes the suite of programs that the Mathematics Department at Texas A&M developed to increase retention rates in this pathway. The suite of programs incorporates placement,
remediation, intervention, monitoring and enrichment for students (PRIMES) in the Engineering Mathematics sequence.

The main components of the PRIMES program are:

1. **Placement**- A Math Placement Exam (MPE) developed in the current NSF STEP grant is now administered to all incoming students who are planning to take Calculus for Engineers. The purpose of the MPE is to better identify which course (PreCalculus or Calculus) is more suitable for the individual student.

2. **Remediation**- For students who do not meet or surpass the cutoff score on the MPE, the Math Department offers several options, all of which are completely online. Each of the different programs is described below:

   (a) **Personalized PreCalculus Program (PPP)**: This three week summer course is for students who took the MPE but scored below the designated cutoff. The course is designed to review the algebra and PreCalculus concepts covered on the MPE in both a synchronous and asynchronous online environment. In the synchronous environment, groups of about 20 students are led by a mathematics tutor. The asynchronous environment provides students the opportunity to improve their individual mathematical weaknesses. Students can retake the MPE, and if they score at or above the cutoff they are permitted to register for Calculus I.

   (b) **Online PreCalculus Course** - This four week summer class is for any student registered for Calculus I. It contains a thorough review of the PreCalculus concepts needed for success in Calculus I at Texas A&M University (including vectors and parametric equations).

   (c) **Bridge-to-Calculus I** - This program is a five day program offered to any student enrolled in Calculus I. The Bridge-to-Calculus program is delivered two weeks before each fall and spring semester starts. The program provides a review of the concepts from PreCalculus essential for success in Calculus I.

3. **Intervention**- Once students are placed in Calculus (or PreCalculus), it is very important to identify “at-risk” students as quickly as possible, preferably in the first few weeks of the semester. The procedures developed by the Mathematics Department will be described in detail in Section 4. After “at-risk” students are identified, it is necessary to “intervene” and prescribe a set of actions for students intended to improve their chances at successfully passing the course, where “success” is defined as obtaining a grade of C or better. This is also known as the Just-In-Time (JIT) program.

4. **Monitoring**- After prescribing a set of actions, it is necessary to monitor whether students actually follow the actions prescribed for them. This is part of a bigger issue, that of “resource tracking.” Identifying and tracking students in need of academic assistance is currently an issue being investigated at the university level at Texas A&M University and is certainly aligned with the goals of the Mathematics Department.

5. **Enrichment**- After a student successfully completes Calculus I, a comprehensive five day
(15 hour) review of Calculus I concepts is provided in order to ready the student for Calculus II.

These programs are the basis for the extensive support network developed for students in the Engineering Mathematics sequence. Faculty at Texas A&M University have conducted a statistical analysis of the MPE test scores. The results of the analysis are summarized in section 8 of this document. Additionally, faculty conducted statistical analyses of grade outcome and retention results over the past five years. These results are summarized in section 9 of this document.

The implementation of the PRIMES program has proven beneficial for the Texas A&M Mathematics Department. Though the focus of the programs outlined above are for students in the Engineering track, the success of these programs has provided the university evidence that these programs do, in fact, increase students success rate in mathematics courses. This has given the department the leverage to develop similar programs for students who are not on the Engineering Calculus track, including students needing to take Business Calculus. As a result, the department has developed two different Math Placement Exams, geared towards different majors. These placement exams are being given to all incoming students, regardless of major.

Finally, in addition to placement purposes, the MPE is now being used to help judge whether students can take both Calculus I and Physics in the same semester. These additional uses of the MPE incorporate some of the broader impacts and unexpected outcomes of the Departments NSF STEP grant.

Descriptions of each of these P-R-I-M-E components are given in the sections that follow.

## 2 Placement

A 33 question placement exam (covering algebra, trigonometry, exponentials, logarithms and other PreCalculus concepts) was developed by instructors in the Department of Mathematics at Texas A&M. Initially, the test was for informational and advising purposes only. Students could register for PreCalculus or Calculus I regardless of their MPE score. In 2011 a minimum cutoff score of 22 was established, meaning that students were blocked from registering for Calculus I if they scored below a 22 on the MPE. This was institutionalized when the student records database (COMPASS) started to record the MPE score for students.

Initially, the cutoff score of 22 was more or less heuristically determined. Later, a more rigorous statistical analysis was performed which verified that students with a score of 22 or higher on the MPE had a 70% likelihood of passing Calculus I. Somewhat paradoxically, after the cutoff score was enforced, very few individuals had scores below 22 in Calculus I so it was no longer true that 70% of students with MPE’s 22 or greater passed. The imposition of a cutoff score changed the demographics (and statistics) of the underlying population of students in Calculus I.

About the time the MPE cutoff score was introduced, an extensive statistical analysis of the MPE
was performed. A statistical measure of reliability (Cronbach’s $\alpha$) was computed, and was found to be 0.88 or higher. This places it in the same range as high-stakes tests such as the SAT and GRE. Using item response theory and confirmatory factor analysis, a uni-dimensional model with a single latent variable was justified [1].

Using a logistic regression model, the cumulative distribution function of the number of people who pass Calculus I (i.e. retention rate) versus MPE was examined. The results are similar to that shown below:

![Figure 1: Grade Predictions](image)

The data came from a sample after the MPE cutoff was imposed. This implies the passing rate of 70% was true for everyone in the class. By the time a student exceeds an MPE score of 28, his or her chances of passing were approximately 90% [2].

Based on the goodness-of-fit of the logistic regression model, retention models have been created that accurately predict the retention rate given the MPE distribution of the incoming students [3].

### 3 Remediation

The department developed a Personalized PreCalculus Program (PPP) for students interested in additional help in passing the MPE. The PPP is a fully online course that uses two electronic platforms: WebMeeting and WebAssign. The content created in WebAssign uses an electronic text authored by one of the Department’s faculty, Dr. Michael Stecher. In addition to the text and algorithmic practice problems, streaming videos and other supporting documents are offered. The cost per student for the PPP is currently $150.00

Recruiting for the PPP begins as early as March. At the end of each week, beginning at Spring Break, emails are sent out to those students who receive a MPE score in the [14, 21] range. Project personnel obtain email and postal addresses, and a personalized email or letter is sent to each identified student. Since the email is sent to the address used for admissions, and the postal mail goes to the students permanent address, in most cases parents have access to the letters of invitation.

Initially the subscription rate to the PPP was about 15% (about one out of seven students contacted
enrolled in the PPP program). Lately, it has increased to over 25%. We believe this is due to an aggressive campaign sponsored by TAMU, reminding students who register for the New Student Conferences (NSC) that they need to take the MPE. This is done every week until students take the MPE.

Students in the PPP program who retake the MPE increase their initial MPE score by approximately six or seven points. Those who register for Calculus I do as well as those with similar MPE scores do.

Since the implementation of the PPP, several challenges have emerged. These challenges are:

1. Many students do not retake the MPE, even after completing the PPP course
2. Some students who score 22 or above on the MPE do not register for Calculus I
3. Students who enter Calculus I with MPE scores in the [22,25] range, remain at risk of getting a D or F in Calculus I.
4. A significant percentage of PPP students exit their initially declared STEM major.

We do not yet know the underlying reasons for these issues. One hypothesis is that the students realize that they have mathematical deficiencies before enrolling in Calculus I or while in Calculus I, and choose to take another path towards graduation (in a non-STEM field).

A second online PreCalculus program, more in the nature of a comprehensive review of PreCalculus, was developed in Summer 2014. It was called the “PreCalculus Bootcamp.” This bootcamp course is based on an interactive e-book authored by Schulz et al, and published by Pearson [4]. It is offered through MyMathLab, a learning management system developed by Pearson. Comprehensive diagnostic exams, as well as pre and post tests, and links to videos, interactive graphics and other documents are available.

A faculty member in the Department of Mathematics (Dr. Sherry Scarborough) taught this as a four week course, meeting for 90 minutes a day. Two tracks were offered: one had a limited enrollment and the other did not. The first track offered synchronous videoconferencing through WebEx with shared audio, video and applications. In addition, Dr. Scarborough developed interactive problems, presented through Pearson’s Learning Catalytics new clicker software [5]. This allowed students the opportunity for real time problem solving, questioning and subsequent discussions. Each session was recorded, and converted to an HTML5 video format (mpeg4) so students could access it at their convenience. A total of 17 students enrolled in this track at a cost of $115.00 per student.

The second track had unlimited enrollment, was asynchronous, and offered full access to MyMathLab, and the e-book. In the asynchronous environment, this track did not contain the live videoconferencing or Learning Catalytics software. Students in this track had access to the session videos. A total of 83 students enrolled in this track at a cost of $103.50 per student.

Access to all content in the two tracks described above was offered to enrolled students for a one-year period of time. This allowed students to review concepts while they were taking Calculus I.
and Calculus II.

The distribution of MPE scores for the 63 students in the online PreCalculus Bootcamp program, who completed Calculus I, is shown below.

![Bootcamp MPE Distribution](image)

Figure 2:

The mean GPR of this group was 2.540. To test for treatment effects (i.e. participation in the boot camp program), a random, stratified set who had the same MPE distribution was chosen from the entire Fall 2014 Math 151 student population, The average grade point ratio (GPR) of this random stratified population was 2.0058, with a standard deviation of 0.1314. The PreCalculus Bootcamp students' GPR corresponded to a z-score of +4.064

This is a statistically significant difference. It is difficult to determine the cause of this difference, since the PreCalculus Bootcamp students were not randomly selected, but were self-selected.

There are at least three factors contributing to the higher GPR of the PreCalculus Bootcamp students. These factors are:

- **Self-selection.** The better students, who are concerned about their preparation for Calculus I, are attracted to a self-paced summer course.

- **Material content.** Alerting better students to potential "PreCalculus misconceptions" positively impacts their performance in the Calculus I common exams, and hence their final GPR.

- **Structure.** The summer PreCalculus Bootcamp course involves numerous forms of technology, requires self-discipline, and good time-management skills, and demands effort on the part of the student during the summer. Students who do well in this format may also do well in Calculus I at Texas A&M since it has an emphasis on technology (Matlab) and requires good time-management and study skills.

Finally, at the close of the Fall 2013 semester, but before Spring 2014, a “Bridge” Program was offered to all students who passed Calculus I. The goal of the Bridge Program was to summarize
the concepts in Calculus I that are absolutely necessary in Calculus II. This program was con-
ducted over a five day period and each meeting was held for three hours. It was offered during the
Winter Break. Approximately 160 students (out of 1686 passing students) enrolled in the Bridge
Program. The subscription rate was about 10%. Based on the demand from the first Bridge Pro-
gram, the Bridge Program was expanded to assist students entering Calculus II. During Summer
2014, three weeks before the Fall 2014 semester started, the Bridge Program was extended and not
only included “Bridge to Calculus I” but also “Bridge to Calculus II.” The second Bridge Program
followed the same structure and philosophy of the original Bridge to Calculus I program but was
modified to essential concepts for Calculus II. During Summer 2014, 241 students enrolled in the
Bridge to Calculus I program, and 77 students enrolled in the Bridge to Calculus II program. The
response rate remained steady at about 10%. It is important to note that the bridge programs are
free.

In summary, the total number of students participating in the three programs (PPP, PreCalculus
Bootcamp, and Bridgeing) was over 650 students for Summer 2014.

To gauge the impact of these various programs, an analysis using the course grade for each student
as a function of MPE and program participation will be conducted. This analysis will be started at
the end of the Fall 2014 semester.

4 Intervention

One of the long term goals of PRIMES is to identify “at-risk” students, where “at-risk” is defined
as a low probability of passing the mathematics course. As part of a joint Math, Science and
Engineering pilot project, performance indicators were studied for a group of about 2500 students.
Analysis revealed at least two key indicators. The first indicator was the student’s course average
after the first Common Exam which occurs approximately five weeks into the semester. The second
indicator is the students’ course average after the second Common Exam, given approximately 9
weeks into the semester. Since the third Common Exam is given approximately two weeks before
the end of the semester, it was deemed too late to be of much use. Interestingly enough, individual
students’ MPE score did not correlate well with success. (This is precisely the reason why we the
cumulative distribution function was used).

Analysis revealed that when the cutoff of 70% after Exam 1 was used as an indicator, less than 4%
of students with averages higher than the cutoff failed, while 70-80% of students below the cutoff
failed. Averages after Exam 2 were even more predictive.

Using this as the identifier of being “at-risk,” emails were sent out to all students identified as
“at-risk” in five Calculus I sections (two instructors) in Summer 2014 inviting them to participate
in various departmental programs - weeks-in-review, help-sessions as well as office hours. A bar
code system was developed to help track attendance through a sheet of bar codes. Students could
use the bar codes in lieu of signing a sign-in sheet for these programs.

Unfortunately, the tracking rate (identifying at-risk students use of resources) was essentially zero.
This led to the fourth component of PRIMES, student tracking.

5 Monitoring

The Mathematics Department currently offers the following (free) resources to students in Calculus I:

1. **Weeks-in-Review.** The contents of the course lecture material are covered early the following week. The format is a two hour live presentation. In the review before the exams, rooms are filled to capacity, sometimes exceeding 300 students. No attendance is taken.

2. **Help Sessions.** Each week, approximately 20 hours of help sessions are offered, some on weekends. These are staffed by math majors or graduate students. Attendance is taken via sign in sheet.

3. **Streaming Videos.** Hundreds of hours of streaming videos are hosted on the math servers. These are either instructional, or problem solving videos. No tracking information is gathered.

4. **Old Common Exams.** 20 years of common exams (with solutions) dating back to 1994 are available on the math servers. No tracking information is gathered.

In order to determine the effect of the monitoring on student performance (and grade outcomes), it is necessary to identify which students use these resources. This should be done in a way that cannot influence their grade (i.e. tracking information is not available to instructors, only departmental and college level administration). To this end, we are doing several things to help track items 3) and 4) above.

Further development of video problems is currently underway. The current plan is to make viewing videos “assignable” hence track-able in WebAssign. Previous common exam problems are in the process of being coded. These problems will be algorithmic (parameterizable) and assignable.

Tracking student attendance is a priority, so much so that Engineering and Physics are assisting us with these efforts. Some of the ways of tracking that have been discussed are:

1. RF chips on student ids - passive
2. Bluetooth or NFC technology (smartphone) - passive
3. Barcode scanners - active
6 Enrichment Programs

Once the student has successfully passed Calculus I, a “bridging” program was offered. The intention was to provide a Course-In-Review, to consolidate student learning after a month long winter break. This program is free, but intensive - three hours a day for five days, just before the Spring semester starts. About 10% of passing students chose to enroll in this free program.

The format is similar to our other online programs - video conferencing (either through Centra WebMeeting or WebEx) which offers live audio/video/desktop sharing. Students have access to problems which they can work out, and then ask the tutor/mentors about.

Tutors (mentors) are typically 2-year or 4-year college instructors, with extensive background in both high school and college level mathematics.

Based on the amount of student interest, bridge programs to Calculus II and III are being developed.

7 Summary

The programs described above are intended to do the following

1. P = PLACEMENT: Place the student in the correct first math course, PreCalculus or Calculus I.
2. R = REMEDIATION: Offer remediation if the student does not pass the placement exam.
3. I = INTERVENTION: Identify at-risk students and provide proven intervention strategies.
4. M = MONITORING: Monitor resource usage by all Students (particularly at-risk students)
5. E = ENRICHMENT: Develop enrichment programs to maximize readiness of outgoing Calculus I students.

These programs include free online resources, and fee-based resources. Fees are typically assessed when there is heavy person-to-person interaction, such as PPP. A pool of talented and trained instructors/tutors/mentors have been identified, and new ones are being trained.

Finally, a comprehensive analysis of performance (grade outcomes and other metrics) and its dependence of a multitude of factors is underway.

The ultimate goal of PRIMES is to develop scalable, sustainable, and effective methods to maximize the retention rate for students in the Engineering Math program. A proven corollary of this is increased retention in all the related STEM disciplines.
<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Students</th>
<th>Mean Difficulty</th>
<th>Standard Deviation</th>
<th>Cronbach’s α</th>
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<td>2008</td>
<td>3792</td>
<td>20.83</td>
<td>7.245</td>
<td>0.898</td>
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<tr>
<td>2009</td>
<td>3530</td>
<td>21.66</td>
<td>7.004</td>
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</tr>
<tr>
<td>2010</td>
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<td>21.97</td>
<td>7.244</td>
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<tr>
<td>2011</td>
<td>4071</td>
<td>22.34</td>
<td>7.081</td>
<td>0.902</td>
</tr>
</tbody>
</table>

Table 1:

8 Analysis of MPE

Note: A number of technical reports and preprints, including this document, may be found at the URL [http://www.math.tamu.edu/~mpilant/MPE_results/index.html](http://www.math.tamu.edu/~mpilant/MPE_results/index.html)

In order to test the reliability of the MPE, we calculated the Cronbach’s α coefficient for more than 15,000 exams. The results are shown below in Table 1.

We also looked at the effect of eliminating one question and re-computing Cronbach’s α. This is shown below in Figure 3.

![Figure 3](image)

A confirmatory factor analysis (CFA) yields a uni-dimensional single latent variable model. An item response theory (IRT) analysis yields a two-parameter model, rather than a three-parameter model. The details of this psychometric analysis can be found in [1].

9 MPE vs Student Performance

Because of the large number of students taking the MPE (over 30,000 so far) and the small number of possible MPE scores (ranging from 0 to 34), there will be a large number of students who
either pass or fail for each possible MPE score. The probability distribution function (PDF) which estimates the probability of an individual student passing Calculus I, for a given MPE, is quite noisy, see below.

![Figure 4:](image)

It is much more efficient to calculate the cumulative density function - the probability that a student passes, given an MPE score less than or equal to S.

![Figure 5:](image)
The effect on retention for the entire Engineering Mathematics Sequence is shown below in Figure 6.

Figure 6:

10 References


5. Learning Catalytics Web Site: [https://learningcatalytics.com/]}