Improved Enrollment and Pass Rates in Calculus
by Werner Horn, Chair of Mathematics
Carol Shubin, Professor of Mathematics

Key Takeaways

- Developed in response to the **crisis in STEM graduation rates and years to graduation**, this innovative model combines **improved information and support for the Math Department calculus placement exam,** pairing of an **existing parent course** with a one-unit **supplemental hybrid course** and **online tutoring** to provide a variety of **interventions and practices to support students** at California State University, Northridge.
- Developed a system that identifies "at-risk-students", that is students who have a high risk of failure, based on their pre-requisite performance. At risk students are required to take the on-line hybrid lab.
- Developed a parallel approach for the courses preceeding and following Calculus I, Trigonometry M104 and Calculus II M150B.
- The model divides instruction among **faculty, teaching assistants, and tutors**, who coordinate content.
- First fully implemented in 2011, the model's **results have been dramatic** — essentially **reversing the downward trend in student success** and vastly improving students' average scores and the distribution of the grades.

M150A Calculus I is a prerequisite for a range of higher-level courses in math and other subjects. Because of this, M150A Calculus I is a gateway course for science, technology, engineering, and mathematics (STEM) fields. M150A directly affects approximately 25% of the total STEM student population of 5000. Secondarily, mathematics service courses impact at least 43 non-mathematical STEM courses required by 25 degrees in Engineering, Computer Science, Mathematics, Physics, Chemistry and Biology.

Since 1999, M150A has had a 50-60% pass rate. Success in this course is highly correlated to retention and timely graduation. Of the CSUN students admitted as first-time freshmen between 1996 and 2002 who entered STEM majors less than 30% completed a degree in 6 years. Of this, only 4%, completed their degrees in 4 years. In examining the data closely to determine what factors led to success, we found that over 80% of entering freshmen who began as a STEM major and took Calculus in their first semester received a degree. Failure to pass Calculus I negatively impacts retention rates and delays degree completion. Thus, the most promising approach to increasing retention of freshmen entering STEM majors is to ensure their timely matriculation in Calculus and required Mathematics courses.

CSUN has developed a technology-enhanced hybrid course model that has both significantly improved student success and proven cost efficient and scalable:

1. Online individualized remediation of prerequisite skills for the MPT.
2. Facilitated group work in a weekly supplemental contact hour.
3. Webwork Online homework with instant feedback.
4. Online math tutoring.

The model components incorporate interventions and practices — such as support for mathematics success, problem-solving in teams, and interaction with instructors beyond the lecture setting — that have proven successful at CSUN and other campuses in supporting students, particularly those from underrepresented minority and disadvantaged economic groups.

Main Accomplishments

We achieved the following goals by pursuing the following student success outcomes:

• increased the passing rates from the historical average of 58% to overall passage rate of 67 %.
• accelerated graduation rates.
• provided in-person and online training materials to help faculty incorporate universal design into their pedagogy.
• developed a set of best practices to train and monitor the tutors.
• created Online Tutorial Center with accessible tools for all students.
• increased participation of all student groups in STEM majors.

Improved Learning Pipeline

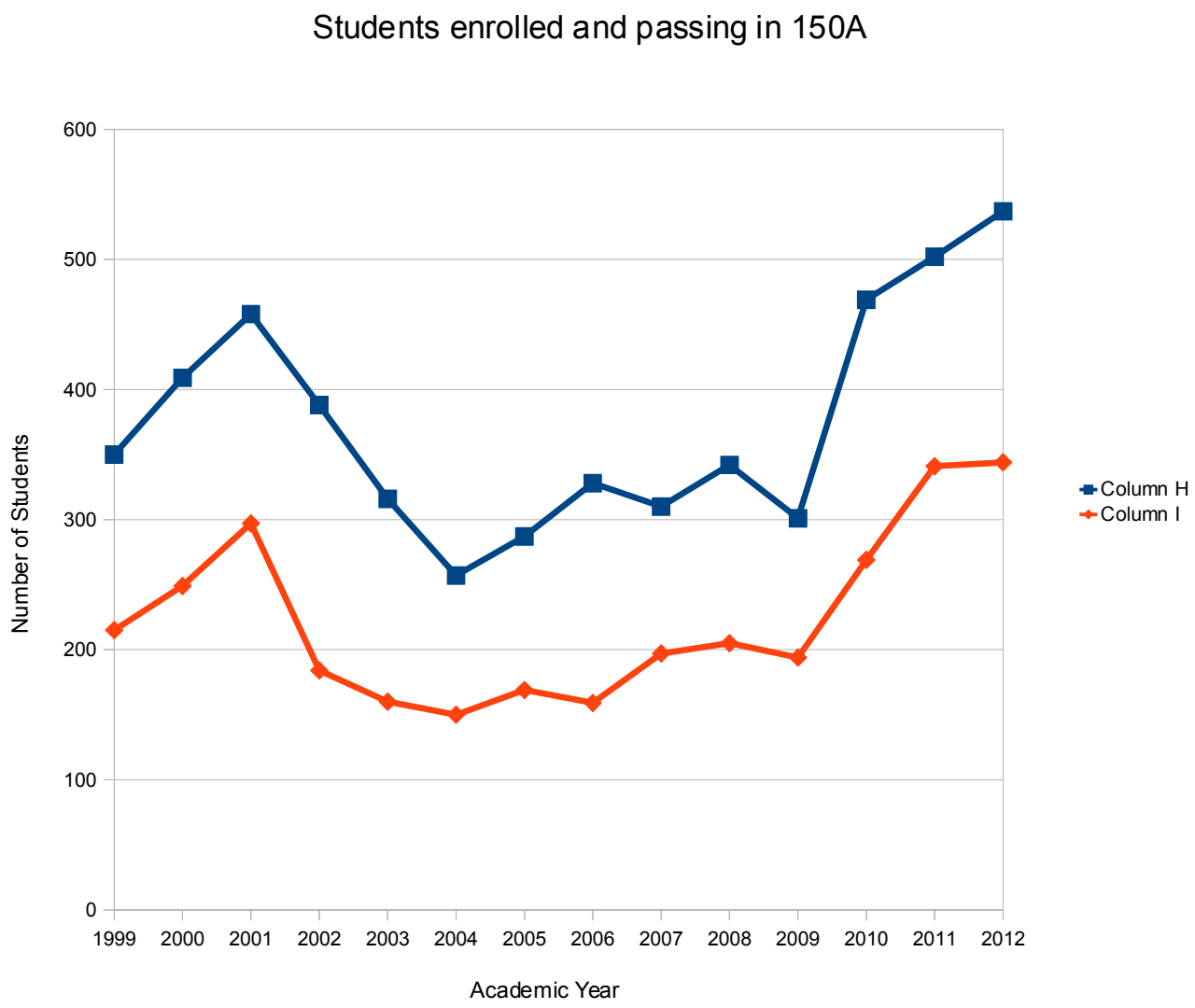
1. improved contact with advisors and students before the Math Placement Test MPT which determines if a student can place into Calculus I.
2. created an MPT study website.
3. added a upplemental instruction laboratory for all at-risk students on Moodle using Webwork for homework.
4. added an Online Tutoring Center on Moodle

Funding and Acknowledgments

Many faculty have collaborated on this project. A major push came, when Dr. Vicki Pedone (Geology), Dr. Cristina Cadavid (Physics), and Dr. Werner Horn got awarded their STEPS (Students targeting Physical Sciences -NSF-DUE 0969627, $1,268,004) grant, which would pay for the development of some of the materials. Alexander Alekseenko, Carol Shubin, and Jacek Polewczakreceived additional support from the Provost's Office and Chancellor's Office for improvements made to MPT Practice Website, ELM CSU Student Success Website, and Online Tutoring System. Many thanks to Provost Harry Hellenbrand for his support for this project.

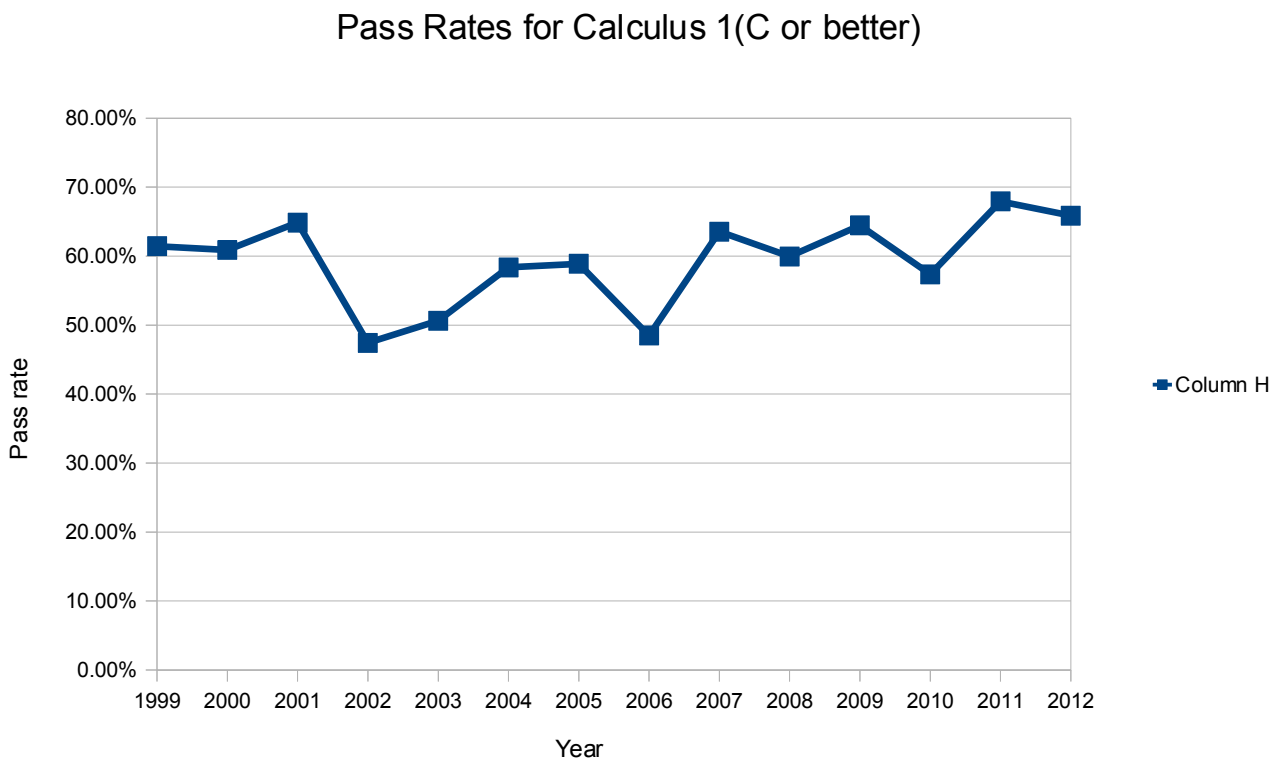
Identifying At-Risk Students
The idea of identifying at-risk-students and increasing their requirements is based on work at Cal State LA by Borislava Gutarts, P.K. Subramanian, and Marshall Cates (http://www.highbeam.com/doc/1P3-1882776341.html). Historical data show that students who enter Calculus I with a grade of B- or better in the pre-requisite course usually have no problem with passing Calculus, however the C students pass at a significantly lower rate. In the new model C students are required to take the hybrid lab.

Student Success
The chart below shows the enrollments for 150A over the period 1999-2012 (blue line). These are annual enrollments excluding summer. The value for a given year is the total enrollment for the academic year starting at this date, so 1999 represents the 1999/2000 academic year. The red line represents the total number of students passing Calculus with a C or better in a given year, starting 2011 it is with a C- or better, as this represents the new threshold for advancing to the next course.



The enrollment data are actual through Spring 2013. The passing data for the 2012/13 academic year are forecasts based on the Fall 2012 pass rates.

The second graph shows the annual cumulative (all sections) pass rate for Math 150A. There are notable dips and increases in this graph. The sharp decline from 2001 to 2002 probably reflects the changes in the ELM and Developmental Math made around that time. With the preparation courses adjusting to this new reality, the rate climbs up to somewhat below its historic average. But the year after it reaches a higher plateau.



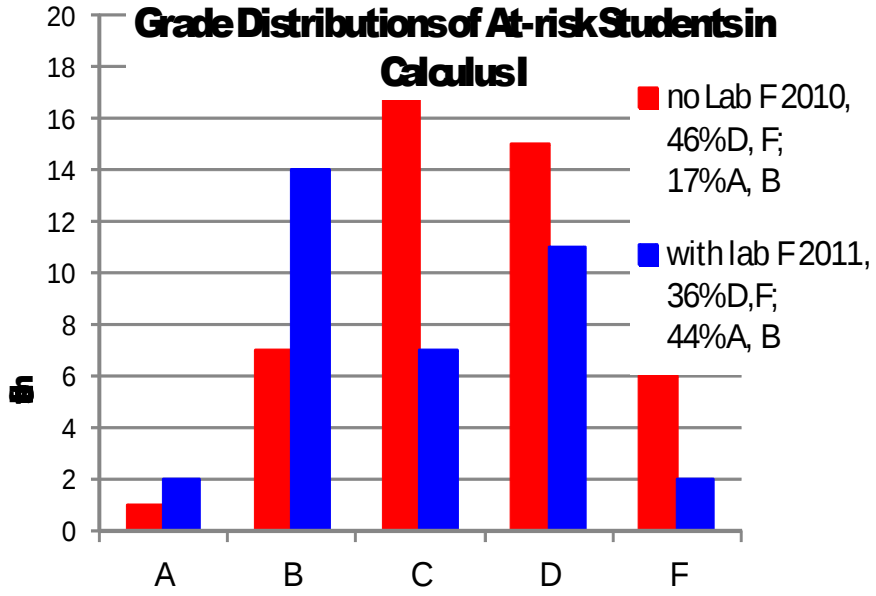
There are several possible explanations for improved pass rates:

- The Calculus book was standardized. Instructors use James Stewart's Calculus textbook.
- Calculus Labs were introduced for students with weak test scores or low grades. Higher prerequisites was instituted for students who are not required to take labs
- Online tutoring was opened Sunday – Thursday evenings.
- Passing standard was changed to C-.

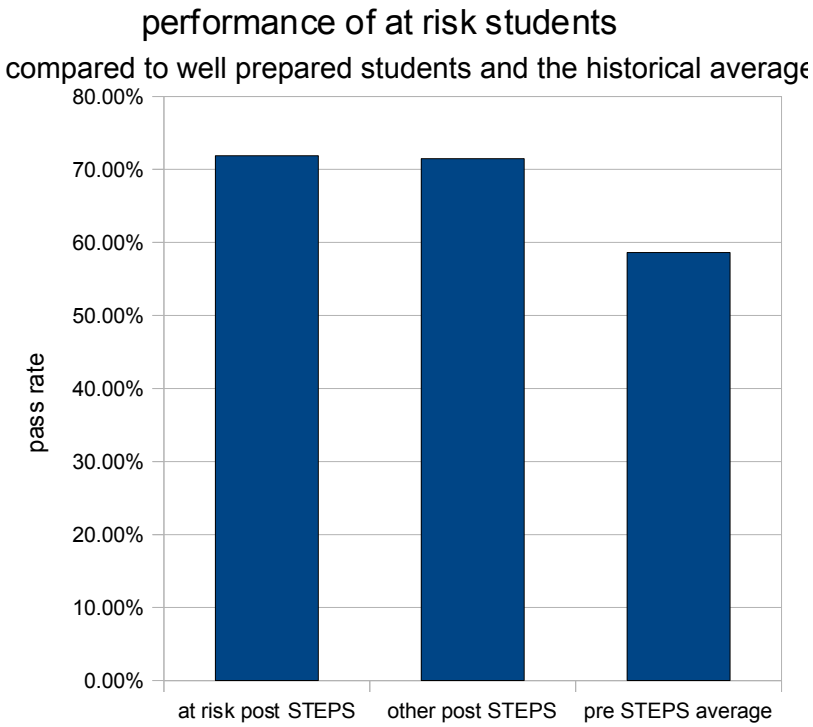
Influences of individual instructors should average out in these data. However, we note that some instructors have significantly lower passage rates than others. Over the years the pass rates of individuals can fluctuate quite a bit. In one instance, one instructor had a pass rate of below 50% in one semester and a rate of close to 90% the following semester. Especially in fall (when students can enroll long before the semester starts), "good" students with early enrollment dates will gravitate to particular sections (based on time and instructor), other sections will have a high percentage of repeaters and students who take Calculus in their Junior year (those students are usually weaker). Popular instructors are those with historically high pass rates and evaluations on the different internet sites. This trend tends to amplify the differences between instructors with high pass rates and low pass rates.

Overall students who participated in the labs have the same pass rates as student who were not required to take the labs because of stronger performance in pre-requisite courses or exams. Note: students receive No Credit in the lab if they fail to participate in more than three sessions.

Grade Improvement



Performance of At-Risk Students in 2011



Improved Information for Students and Advisors about MPT

The Mathematics Placement Test (MPT) is a CSUN test used to determine eligibility for enrollment in MATH 102, 103, 104, 105, 150A and 255A, and must have been taken within the year preceding enrollment in these courses. The MPT does not replace the ELM requirement, but is used in addition to the ELM to determine eligibility for enrollment. Part I of the MPT consists of questions from intermediate algebra. Part II of the MPT

consists of questions on trigonometry and advanced topics from intermediate algebra (precalculus). A qualifying score on Part I is required for entry in MATH 102, 103, 104 and 105. Qualifying scores on both Parts I and II are required for entry into MATH 150A and 255 A.

1. **i**mproved preparation for the MPT http://mathweb1.sandbox.csun.edu/mpt/
2. met with Testing Service staff and had better coordination with the Undergraduate Advisors
3. increased the time available to complete the exam to one hour and thirty minutes.

Introduction of Supplemental Labs
To study the impact of the calculus labs we consider the students who were required to enroll in these labs and received credit in the last three semesters and study their pass rates. Of the 457 students who enrolled in MATH 150AL in the period from Fall 2011 through Fall 2012, 281 passed the lecture, making the success rate for these at risk students 61.5%. However, if we just consider the students who received credit for MATH 150AL (i.e. the students who stayed in the lab until the end), their success rate is at 71.9%, almost identical to the rate for student who did not need to take the labs (71.5%). The message is clear, if you need to take the lab, and you take it seriously, your chance of success is the same as a student who does not have the lab requirement. Moreover, it is save to assume that the "good" students (without the lab requirement) passed the course at around 70% in the previous years. The increased overall rate of success is likely entirely due to the "less prepared students", who get the needed boost from the labs.

M150AL Calculus I Laboratory Moodle currently resides on a Math Department Moodle site.
http://mathweb1.sandbox.csun.edu/moodle1/

During the first week of the lab, students retake the MPT. Based on test results, students are directed to review using online free, open-source homework system called Webwork which contains a national database of math problems. Although Webwork does not adjust its content to student performance, it does serve as a mechanism to get homework and MPT remediation back to the students and to give them unlimited practice and instant feedback on their work. Remediation topics include fractions, function, geometry, and trigonometry. For the supplemental contact hour, we use pen-and-paper workbooks aligned with the textbook ; here, the focus is on the act of writing mathematics as a connection between lecture, homework, and exams. These elements are coordinated with the work of the faculty and TAs, as well as with other course materials: lecture notes, supplemental contact hour workbooks, homework problems, and exam problems.

We included captioned calculus videos on the most difficult topics. These videos were made by Alex Alekseenko, with the support of the Petri Grant.

Teaching Assistants are provided with a *Common Errors Manual in Calculus* by Mark Schilling.

Students review proper mathematical grammar are quizzed on "How to Write Mathematics."

M150AL students complete a Survey at the end of lab for assessment of the usefulness of the labs.

Online Tutoring Center
During Summer 2010, we set up a site on Moodle as the initial instance. The site has been open every semester since then. It is monitored Sunday – Thursday evenings by tutors and a faculty member.

The Online Tutoring Center services are closely aligned with the M150A curriculum. Each section of the syllabus is covered. Assistance is offered for homework and test preparation.

Both the Online Tutoring Center site and the tutors are periodically assessed for quality of tutoring services and administer the measures in the beginning of each semester and in the middle of it. Each tutor is evaluated on pedagogical maturity, ability to communicate, use learning resources, ability to accommodate different learning styles, and effectiveness in answering student question.

We developed measures to assess the usage and of the web-space such as counting how many students visited the web-space, asked questions on the web-space, acknowledged that using the web-space helped them answer their question or formed discussions.

The Online Math Tutoring Center fits in well with the CSU's Affordable Learning Solutions (AL$) initiative improves the choice, affordability and accessibility of educational content for students through innovative delivery of open educational resources.

We believe that we have established a high impact practice. Students and student tutors engage in interactive experiential online learning community. The Online Tutoring Center's evening hours and convenience appeals to a wide group of students.

Cost - Benefit Analysis
This model of instruction comes at a higher cost to the campus, however, the increased retention comes at a net savings to the student. The hybrid labs do not require any special facilities. We use standard classrooms for the contact hours and standard computer labs to support the lab's online component. At CSUN, no additional facilities have been constructed for this purpose.

Additional Plans for Collection of Assessment Data
From the Moodle Statistics, we can evaluate use of online tutoring center by looking at activity logs and track the types of questions asked and how they are answered. From the Math Department or Institutional Research, we will collect final exam results and compare with past results. We will keep track of students outcomes in mathematics M150B (or M150A, if they failed) the semester after completing M150A and try to assess the value-added from the tutoring center. If a student failed, we will review their exams and tutoring center records.

We will research student preparedness background including high school of origin, SAT or ACT results, ELM, MPTI and MPTII results and other available pre-college indicators such as GPA. We will also collect data on past courses attempted at the college level. We will collect data generated from our course coordinator including comparison of instructor grading and class averages by instructor. We will attempt to review final exams over time for consistency in difficulty. We will survey and have focus groups with students, tutors, ATI staff and faculty participants to find out what worked and how could the tutoring center be improved. We will also look for any unusual patterns or behavior that may emerge over time.

Assessing the Assessment Process
Our initial formal assessment will be made during Intersession 2011 and although we monitor the site daily and make many adjustments as we go. Results from assessment will be used to improve the sites effectiveness. Ineffectual material or methods will be dropped or modified. After making correlations between data, we may more clearly early indicators of student outcomes and learn what strategies work best to circumvent failure. We note that assessment practices are on-going. Best practices and reports are posted on CIELO's Ideashare.

Accessibility
ATI tested the tutoring website for compliance with the World Wide Web Consortium's (W3C) Web Accessibility Initiative (WAI) and the Section 508 Standards for Electronic and Information Technology (http://www.access-board.gov/sec508/guide/1194.22.htm). General discussions about universal design and accessibility have been initiated with Susan Cullen and Sandra Caesar.

Phase II

We will also study the so-called “achievement gap”. We will focus attention on the performance of underrepresented minority and low-income students, most of whom are the first in their families to attend college. Failure to pass Calculus I negatively impacts STEM retention rates and delays degree completion.

In Phase II, we plan to particularly study whether the tutoring service particularly supports the needs of students with disabilities. This group of students takes twice as long to matriculate a Mathematics course. Enrollment data shows that students with disabilities are very interested in pursuing STEM degrees: 32% more students with disabilities are enrolled in STEM program as compared to all students. However, 40% less STEM degrees are awarded to students with disabilities. Our goal is to broaden the participation and achievements of students in all fields of STEM education and associated professional careers.

Develop measures of implementing practices of universal design and training tutors and faculty to follow these practices.

1. In coordination with Sue Cullen, we will develop a table of different learning styles and check whether materials are available to address these styles.
2. How many training sessions were available to tutors and faculty in using universal design each semester?
3. How many tutors and faculty members attended the sessions?

Conclusion

The hybrid course model has proven effective at CSUN in turning around high-failure-rate math classes. This is a cost effective scalable project.

The model does require well-coordinated course materials, access to technology, and a teaching staff willing to coordinate their work in order to improve student performance and ultimately lessen the faculty's workload, while training math majors as tutors and graduate students as teaching assistants.