Executive Summary for the Self-Review of the Applied Mathematical Sciences Program at University of California, Merced

March 8, 2010

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1 Mission Statement

The overarching mission of the Applied Mathematical Sciences program is to enable students with the skills and learning experiences needed to solve interdisciplinary mathematics problems relevant to government, industry, business and academic research. In carrying out this mission, the Applied Mathematical Sciences program will foster the intellectual growth of individuals who will develop analytical and computational frameworks to solve society's challenging and important problems of today and beyond. The program in Applied Mathematical Sciences contributes to the greater mission of the University of California, Merced (UC Merced)[1] and the School of Natural Sciences[2] through its research, teaching and service.

The study of applied mathematics takes on a broad variety of meanings. The Applied Mathematical Sciences program at the University of California, Merced defines applied mathematics as the application of modeling, analysis and scientific computing to solve problems relevant and important to the real world. This focus on applications to real-world problems does not imply that this program abandons or ignores rigorous mathematics. In fact, this program emphasizes the use of rigorous mathematical treatments to problems of practical interest. It is true that in the study of practical problems, one cannot always develop a complete and rigorous mathematical theory that one aspires to create for purely abstract mathematical problems. For applied problems, we rarely have all of the information required to solve the mathematical problem at hand. Data are always incomplete and noisy. However, striking an optimal balance between complete abstraction and pratical applicability is an interesting mathematical challenge in and of itself. It is this balance that this program strives to achieve.

The Applied Mathematical Sciences program at UC Merced seeks to fulfill its research, teaching and service mission in three distinct areas:

- **Lower Division Service Courses in Mathematics** – The Applied Mathematical Sciences program offers lower division mathematics courses required for many of the majors at UC Merced. Our objective here is for students to learn the fundamental problem-solving skills needed to succeed in their own academic goals and objectives. For that reason, we emphasize learning mathematics conceptually and concretely by exploring topics analytically, graphically, computationally and verbally.

- **Undergraduate Major and Minor in Applied Mathematical Sciences** – The Applied Mathematical Sciences program offers an undergraduate major leading to a B.S. degree in Applied Mathematical Sciences. There is also an Applied Mathematical Sciences minor for students in other majors seeking more training in applied mathematics. The curriculum is designed to provide courses in the fundamentals while allowing for building expertise in an application area through the emphasis tracks.

- **Graduate Studies in Applied Mathematics** – The Applied Mathematical Sciences program offers a multidisciplinary research and training program for Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) students who want to study applied mathematics. A requirement of all graduate students is gaining experience teaching undergraduate students. This requirement provides graduate students an invaluable experience that has important intellectual and practical relevance to their education. Moreover, these graduate student teachers provide an important component in the education of our undergraduate students.

[1] `http://www.ucmerced.edu/about_ucmerced/mission.asp`
[2] `http://naturalsciences.ucmerced.edu/about-school`

2 Learning Goals and Outcomes

The Program Learning Outcomes for the Applied Mathematical Sciences program are given as follows.

> Upon graduating, we expect students completing the Applied Mathematical Sciences major to have become *effective problem-solvers*, meaning that student will be able to
>
> 1. Solve mathematical problems using analytical methods.
> 2. Solve mathematical problems using computational methods.
> 3. Recognize the relationships between different areas of mathematics and the connections between mathematics and other disciplines.
> 4. Give clear and organized written and verbal explanations of mathematical ideas to a variety of audiences.
> 5. Model real-world problems mathematically and analyze those models using their mastery of the core concepts.

The Applied Mathematical Sciences program learning outcomes (PLO) were developed during the 2008-2009 academic year by the applied mathematics faculty as part of the campus-wide preparation of its Capacity and Preparatory Report for Initial Accreditation[3]. We refer to each of the enumerated items above as PLO 1, PLO 2, PLO 3, PLO 4 and PLO 5 throughout the remainder of this report.

The Applied Mathematical Sciences major and its program learning outcomes reflect at least four of Univeristy of California, Merced's Eight Guiding Principles of General Education[4] explicitly in the following ways.

- *Scientific literacy* – Students take a broad variety of science courses that are required for the School of Natural Sciences as well as those courses within each student's emphasis track. (PLO 1-3, 5)
- *Decision making* – Students develop mastery of quantitative skills that help to form an important component in making complicated decisions. (PLO 1, 2)
- *Communication* – Students develop their ability to give clear and organized written and verbal explanations of mathematical ideas to a variety of audiences. (PLO 4)
- *Self & Society* – Students learn to recognize the relationships between different areas of mathematics and the connections between mathematics and other disciplines which brings about awareness of diverse perspectives. (PLO 3, 4, 5)

UC Merced is a student-centered research university. To that end, Applied Mathematical Sciences students learn many of the fundamental skills needed to perform theoretical and computational research. The faculty are dedicated to providing research opportunities for students. Students have already participated in research with applied mathematics faculty as well with collaborative multidisciplinary teams of faculty where they can see first-hand the impact that their theoretical and computational work is having on an application field.

In addition to aligning with the guiding principles of the entire university, the Applied Mathematical Sciences program complements the vision and mission of the School of Natural Sciences[5]. The Applied

[3] `http://accreditation.ucmerced.edu/sites/accreditation/files/public/Required%20Essays.pdf`
[4] `https://collegeone.ucmerced.edu/content/guidingprinciples`
[5] `http://naturalsciences.ucmerced.edu/about-school`

Mathematics program contributes actively to the goal of providing students a multidisciplinary and interdisciplinary education. This program does so by a strong commitment to innovative undergraduate curricula. Like other programs in the School of Natural Sciences, Applied Mathematical Sciences uses a "core + emphasis" curricular model. The core is designed to give students a rigorous learning experience in analytical and computational mathematical analysis and methods. The emphasis tracks are comprised of significant coursework in another field of study which allows students to study a broad spectrum of problems across a number of disciplines.

2.1 Assessment of Program Learning Outcomes

The applied mathematics faculty are involved actively in assessment of the Applied Mathematical Sciences program. Since this group of faculty is relatively small (8 senate faculty members currently), we have chosen to work together as a whole committee to manage the program. Ever since the 2007-2008 academic year, the applied mathematics faculty have met after each semester to go over student data we have been acquiring for each of the courses. Moreover, this group of faculty holds a discussion on what worked well and what items require attention and change. In addition, the applied mathematics faculty and staff discusses and plans the instructional staffing of courses for the upcoming semester. An important part of this discussion is how any decisions translate to larger issues within the School of Natural Sciences. Very often, these discussions lead to a strategy for informing and working with the School of Natural Sciences Dean's Office to ensure that these decisions are commensurate with what the other programs in the school are doing. As of the 2008-2009 academic year, the applied mathematics faculty have instituted subcommittees charged with overseeing the management of the lower division service courses, the upper division core courses and the graduate courses throughout the entire academic year[6].

These regular meetings serve several purposes. For example, they provide an opportunity for the applied mathematics faculty to evaluate continually the Applied Mathematical Sciences program. These meetings keep all of the applied mathematics faculty abreast of the issues that the entire program faces. They provide new faculty the opportunity to become acquainted with the management of the program directly so that they can learn quickly how they can participate actively in the program. Finally, these meetings help the applied mathematics faculty to align their work with that of the School of Natural Sciences and the university.

As a result of these meetings, the applied mathematics faculty have made several changes already to the Applied Mathematical Sciences program to achieve better its program learning outcomes. We list these changes below.

- Restructured student placement tests
- Restructured Math 5: Pre-calculus
- Adopted new calculus textbook
- Developed a new calculus sequence
- Reorganized the core curriculum for the Applied Mathematical Sciences major

More details on these programmatic changes that the applied mathematics faculty have made appear in the status report in Section 11.

[6] see Section 2 of the "Data Section for the Self-Review of the Applied Mathematical Sciences Program at UC Merced" for more details.

2.2 Existing Formal Assessments

As part of the Applied Mathematical Sciences contribution to the university-wide Educational Effectiveness Review for Initial Accreditation, the applied mathematics faculty have conducted an initial assessment of PLO's 1 and 2[7]. The applied mathematics faculty have decided to do an initial assessment of PLO's 1 and 2 in the two critical "transition" courses: Math 121 and Math 131. Math 121 is the first upper division course for the major in which students learn intermediate and advanced analytical methods for solving ordinary and differential equations. Math 131 is the first upper division course for the major in which students learn numerical analysis.

In this initial assessment, the faculty assessed student work by applying an initial rubric to embedded homework and exam questions. The applied mathematics faculty found that there was a diversity of opinions regarding student performance. Through a subsequent discussion, the applied mathematics faculty found that the diversity of results lies in each faculty member's application of the rubrics to the student solutions. The faculty agreed that using only three tiers for assessment (i.e. good, fair and poor) is too coarse. For future assessments, the applied mathematics faculty plan to use a rubric based on the "Holistic Grading" that they use often for grading student work.

In addition to the embedded questions, we conducted a student focus group to obtain some indirect evidence to evaluate. The students gave statements about the Applied Mathematical Sciences program that were largely positive. From the results of this student focus group discussion, the applied mathematics faculty gained a lot of valuable insight from the students that we plan to use to improve the curriculum. In particular, the applied mathematics faculty are considering ways to provide students more early computer programming experiences, which the students requested explicitly. In addition, the applied mathematics faculty are considering novel ways to incorporate the development of mathematical communication skills (written and verbal) throughout the curriculum.

2.3 Proposed Plan for Future Assessment

The Applied Mathematic Sciences program is planning to perform formal assessments of all of the PLO's over the next several years. The document `AMS PLO Assessment.pdf` gives several items that the applied mathematics faculty will consider in the near future as we prepare for additional assessments. In addition, we anticipate two major items to consider for future assessments.

- Evaluating the effectiveness of our lower division mathematics courses for preparing students for success in the majors that these courses serve, include the Applied Mathematical Sciences major.
- Evaluating the effectiveness of our upper division mathematics courses for fulfilling the academic mission of the Applied Mathematical Sciences program.

The lower division mathematics courses are extremely important courses that serve the entire campus. Assessing the effectiveness of these courses necessarily requires input from all of the other programs on campus to whom those courses serve. In consulting with colleagues at our sister campuses, we have learned that the Department of Mathematics at UC Davis holds a regular "calculus summit" for representatives from other programs to discuss the expectations and the overall mathematical preparedness of students coming from lower division mathematics classes. The applied mathematics faculty plan to initiate a similar "lower division mathematics summit" in the near future. In doing so, we hope to collect valuable input that we will then use to assess our lower division mathematics courses.

[7] See the file `AMS PLO Assessment.pdf` accompanying this report.

For the upper division mathematics courses, there remains a great deal of assessment to be done. Provided that we develop and deliver the capstone modeling course as scheduled, we will be analyzing student data to investigate this program's achievment of its program learning outcomes. Other important measures include the analysis of alumni success in graduate school and the job market. Using results from these assessments, the applied mathematics faculty will re-evaluate the Applied Mathematical Sciences major and make changes continually to ensure that those students are earning a degree that makes them competitive nationally in their future goals and endeavors.

3 Curriculum

3.1 Core Courses

The core courses in the Applied Mathematical Sciences program are given below.

- *Math 121: Appied Mathematical Methods I – Fourier Analysis and Boundary Value Problems Introduction to Fourier series*

  This course is offered every Fall Semester. It covers the physical derivation of canonical partial differential equations of mathematical physics (heat, wave and Laplace's equation). Students learn separation of variables, Fourier series, Fourier integrals and general eigenfunction expansions.

- *Math 122: Appied Mathematical Methods II– Complex Variables and Applications*

  This course is offered every Spring Semester. It introduces students to complex variables, contour integration and theory of residues. Students learn also how to solve partial differential equations by Fourier and Laplace transform methods.

- *Math 131: Introduction to Numerical Analysis*

  This course is offered every Fall Semester. It is an introduction to numerical methods with emphasis on algorithm construction, analysis and implementation. Students learn programming, round-off error, solutions of equations in one variable, interpolation and polynomial approximation, approximation theory, direct solvers for linear systems, numerical differentiation and integration and initial-value problems for ordinary differential equations.

- *Math 132: Numerical Solution of Differential Equations*

  This course is offered every other Spring Semester in alternation with Math 142. It is a continuation of Math 131. Students learn how to solve numerically initial-value problems for ordinary differential equations, iterative techniques for solving linear systems, numerical solutions of nonlinear systems of equations, boundary value problems for ordinary-differential equations and numerical solutions to partial-differential equations.

- *Math 141: Linear Analysis I*

  This course is offered every Fall Semester. It covers applied linear analysis of finite-dimensional vector spaces. Students learn matrix algebra, vector spaces, orthogonality, least-squares approximations, eigenvalue problems, positive definite matrices and the singular value decomposition with applications in science and engineering.

- *Math 142: Linear Analysis II*

  This course is offered every other Spring Semester in alternation with Math 132. It introduces students to applied linear analysis of infinite dimensional vector spaces. Students learn inner product spaces, operators, adjoint operators, Fredholm alternative, spectral theory, Sturm-Liouville operators, distributions and Green's functions with applications in science and engineering.

3.2 Emphasis Tracks

Students in the Applied Mathematical Sciences major must complete at least 17 units of approved course work from other programs toward the completion of an emphasis track. At least 10 of these 17 units must be upper division courses. Some examples of emphasis tracks include physics, computational biology, economics, computer science and engineering, and engineering mechanics. In addition, students may create their own customized emphasis track with approval by the applied mathematics faculty so that they may pursue their own individual academic interests.

3.3 Elective Courses

At present, the Applied Mathematical Sciences program does not offer any elective courses within the program. There are some developments of new, elective courses in progress. However, the core is the top priority for the applied mathematics faculty until the number of faculty grows to cover adequately the teaching needs for the core.

3.4 Changes to the Curriculum

This is the first review for the Applied Mathematical Sciences program. At present, the applied mathematics faculty have made some changes to the core curriculum. These changes are described in detail in Section 11.1.5. These changes are currently under review by Undergraduate Council. A summary of the changes the applied mathematics faculty have made is given below.

- Eliminate Math 121 and replace it with a new course, Math 125: Intermediate Differential Equations.
- Eliminate Math 142 and replace it with a new course, Math 126: Partial Differential Equations.

The reason for these changes is to provide students a three-course sequence (starting with Math 24: Linear Algebra & Differential Equations) that builds and develops student skills in analytical solution methods more smoothly. The applied mathematics faculty decided that the current core curriculum does not achieve this development smoothly enough.

4 History of Program

The documentation of the history of the Applied Mathematical Sciences program in the manner given by the "Undergraduate Program Review Guidelines" is as follows.

4.1 Date the program was approved and date admissions were open

Several of the lower division mathematics courses were created and approved by the founding faculty prior to the arrival of the first applied mathematics faculty. Most of the early effort by the founding applied mathematics faculty focused on the lower division mathematics courses needed for the opening of the campus, *e.g.* Math 5, Math 21 - 24 and Math 32. In January of 2005, the School of Natural Sciences held a retreat to discuss strategic planning. During that retreat, the founding applied mathematics faculty developed a proposal entitled, "A Program in Applied Mathematics" (see the file `UCM Applied Math.pdf`). This strategic planning proposal emphasized research initiatives and the development of a graduate group. It was not until April, 2005 that the founding applied mathematics faculty wrote a proposal for the "Mathematical Sciences" major (see the file `Mathematics majorrevised4.18.05.pdf`). Undergraduate Council (UGC) approved this proposal, after revisions (see the file `mathmajor5.23.05.doc`). The major was available for freshmen students starting in the 2006-2007 academic year. It was available for junior transfers starting in the 2008-2009 academic year.

4.2 Name changes or mergers of the program and dates associated with those changes

In Fall 2006, the applied mathematics faculty submitted a request to change the name of the major to "Applied Mathematical Sciences" to be more explicit about the program's emphasis on applying mathematics to real-world problems of practical interest.

4.3 Administrative home of the program

The Applied Mathematical Sciences program is within the School of Natural Sciences. Currently none of the core applied mathematics faculty have appointments elsewhere. However, there are several affiliate faculty from all three schools on campus.

4.4 Degree(s) offered

The Applied Mathematical Sciences program offers a B.S. degree in Applied Mathematical Sciences and an M.S. and Ph.D. degrees in Applied Mathematics.

4.5 Program learning goals and outcomes

See Section 2.

4.6 Degree requirements – date of the last version required by UGC and the URL where posted.

The following degree requirements are available in the current catalog as well as on the Applied Mathematical Sciences website for the major, `http://appliedmath.ucmerced.edu/major-requirements.html`.

Students majoring in Applied Mathematical Sciences must adhere to all UC Merced and School of Natural Sciences requirements. For the Math/Science Preparatory Curricula, students majoring in Applied Mathematical Sciences must take:

- Math 21: Calculus I [4 units]
- Math 32: Probability & Statistics [4 units]

- Phys 8: Introductory Physics I [4 units]
- CSE 20: Introduction to Computing [4 units]
- CHEM 2: General Chemistry I [4 units]

The additional requirements that must be met to obtain the B.S. degree in the Applied Mathematical Sciences at UC Merced are:

Applied Mathematical Sciences Requirements (63-64 units): The Applied Mathematical Sciences major consists of 16 courses (5 or 7 lower division and 9 or 11 upper division, depending on the emphasis track chosen) designed to give all students a common foundation of core knowledge specific to the discipline, plus breadth in an application area.

- Lower division courses (20 Units)
  - Bio 1: Contemporary Biology, ESS 1: Introduction to Earth Systems Science or ESS 5: Introduction to Biological Earth Systems[8] [4 units]
  - Math 22: Calculus II [4 units]
  - Math 23: Vector Calculus [4 units]
  - Math 24: Linear Algebra and Differential Equations [4 units]
  - Phys 9: Introductory Physics II [4 units]
- Upper division courses (24 Units)
  - Math 121: Applied Math Methods I [4 units]
  - Math 122: Applied Math Methods II [4 units]
  - Math 131: Numerical Analysis I [4 units]
  - Math 132: Numerical Analysis II [4 units]
  - Math 141: Linear Analysis I [4 units]
  - Math 142: Linear Analysis II [4 units]
- Emphasis tracks (19-20 Units)

  The student must complete at least 19 units of approved course work from other programs toward the completion of an emphasis track. At least 12 of these 19 units must be upper division courses. Some examples of emphasis tracks include physics, computational biology, economics, computer science and engineering, and engineering mechanics. These examples appear in the sample course plans. More application themes will become available as new programs on campus develop. The student may design their own emphasis track with approval from the faculty program leads for the Applied Mathematical Sciences major.

4.7 Advising guidelines

At present, there are no formal advising guidelines for the Applied Mathematical Sciences major beyond the documentation of the degree requirements. However, the applied mathematics faculty work closely with the School of Natural Sciences advising staff to clarify policies and procedures for this program. The applied mathematics faculty will consider the development of more formal guidelines in the near future.

[8] For the Computational Biology emphasis track listed below, students must take BIO 1 and BIO 1L: Contemporary Biology Lab

4.8 Dates the last review was initiated and closed

This review is the first one for this Applied Mathematical Sciences program.

5 Comparison Programs

Nearly all applied mathematics and/or computational mathematics programs at the other UC campuses are programs or specializations within their respective mathematics department. One exception is UC Santa Cruz. They have an Applied Math and Statistics department in the Baskin School of Engineering that is separate from the Mathematics department in the Division of Physical and Biological Sciences. This Applied Mathematics and Statistics department has a graduate program and undergraduate minors in applied mathematics and statistics. There is also the Computational Science and Engineering program at UC Santa Barbara. This is a joint program of mathematics, mechanical & environmental engineering, computer science, electrical & computer engineering and chemical engineering. However, this is a graduate program only.

A direct comparison of the Applied Mathematic Sciences program at UC Merced with other UC programs is difficult, as no other program has a similar structure. This difference is not accidental. We have chosen deliberately to position ourselves in a way that emphasizes applications. In particular, this program require explicitly that students choose an emphasis track in which they take upper division courses, so that they can apply the mathematical techniques they learn in their applied mathematics courses. This program promotes interdisciplinarity directly, but it does come at the expense of a deeper mathematical training. Other Applied Mathematics programs in the UC system all require their students to take more mathematics courses, but do not require their students to learn another field in which to apply mathematics.

There are a few other notable programs in applied mathematics nationally. The programs most similar to this one are in the Departments of Applied Mathematics at University of Washington and University of Colorado at Boulder. These two programs as well as nearly all of other comparable programs co-exist with a traditional pure mathematics program.

Historically, applied mathematics departments and programs have developed after forming a traditional mathematics department. At UC Merced, we have been developing applied mathematical science alongside the other innovative programs in physical science, biological science, earth systems science, and computer science. This co-development of applied mathematical sciences with other programs on campus is a signature for this program and for UC Merced. Because applied mathematicians are trained to be interdisciplinary, they can act as one unifying group on campus who lead the charge for interdisciplinary research and education.

6 Strategic Plan

6.1 Curricular Evolution

The curriculum of the Applied Mathematical Sciences is continually evolving to meet the needs of its students as well as make the best use of growing faculty expertise. Since the applied mathematics faculty have been designing the curriculum continually and developing new courses for it over the past five years, we anticipate making more changes as they learn more about how effective the curriculum is at achieving the program learning outcomes. Already, as documented in Section 3.4, the applied mathematics faculty have made changes to the curriculum as they have learned how to teach students more effectively. There

are no specific plans or time-line for this evolution. Rather, the applied mathematics faculty will design, develop and deliver new courses as prototypes, very often using student input, and make changes and adjustments as necessary. For example, this initial review has provided the applied mathematics faculty the first real opportunity to evaluate carefully the curriculum in its entirety. In doing so, we have been making the changes documented in Section 3.4. Moreover, this evaluation has helped the applied mathematics faculty in developing more frequent assessments as part of its regular duties for each semester.

6.2 Changes in the Student Population

The student population at UC Merced is growing rapidly. However, the number of Applied Mathematical Sciences majors is relatively small. The applied mathematics faculty anticipate a reasonable rate of growth (in comparison to the projected growth of applied mathematics faculty) in the major over the next several years. Nonetheless, the Applied Mathematical Sciences program will require several more faculty needed to sustain this growing program. Within the School of Natural Sciences Strategic Plan[9], the applied mathematics faculty call for approximately one new FTE per year up to approximately twenty faculty total for the growth rate of faculty.

Table 1 shows the progression of the student-to-faculty FTE ratios over the past 5 years. These data are taken from Tables A and D of the file `UCM Academic Program Review Data - Math.xlsx` prepared by the Department of Institutional Planning and Analysis. These data show that the student-to-faculty FTE ratios are high, but not extremely so. It is clear also from the data there is a very fast growth in the student population. To maintain reasonable student-to-faculty FTE ratios, it is crucial that the growth in applied mathematics faculty continue as stated in the School of Natural Sciences Strategic Plan to meet this ever-increasing demand.

Table 1: Summary of faculty workload/productivity.

	AY 2005-6	AY 2006-7	AY 2007-8	AY 2008-9	AY 2009-10
Faculty FTE (fFTE)	N/A	9.75	10.70	14.3	15.5
Student FTE (sFTE)	131	190	261	309	396
sFTE/fFTE Ratio	N/A	20	24	22	26

The demand for teaching the lower division mathematics courses is growing at an enormous rate which far exceeds the applied mathematics faculty's capacity. To meet this demand, the applied mathematics faculty and the School of Natural Sciences hire several staff lecturers each year to teach these courses and make use of graduate student teaching assistants. Although staff lecturers and teaching assistants provide a valuable and necessary service by teaching these courses, there are several ramifications that may or may not be understood.

Staff lecturers and teaching assistants require continuous support and oversight throughout each semester. These duties are the responsibility of the applied mathematics faculty and the School of Natural Sciences. Even though the applied mathematics faculty largely do not teach these lower division service courses, they are involved heavily each semester with visiting classes, providing advice to staff lecturers and performing nearly all of the major administrative tasks. Each of the applied mathematics faculty spends a great deal of time each semester with administrative tasks associated with lower division mathematics courses, even though they may or may not be serving as an instructor of record for one. This service is not acknowledged

[9] `http://naturalsciences.ucmerced.edu/sites/naturalsciences/files/public/documents/strategicplan.pdf`

as a formal teaching effort. For example, this work does not earn teaching credit or service recognition. To that end, incentivizing faculty to continue to do this work is a challenge that will need addressing in the very near future. An inadequate solution to this problem affects adversely the quality of instruction that our students receive.

The number of staff lecturers that the applied mathematics faculty can hire is subject to budgetary constraints. These budgetary constraints are often at odds with the student demands for classes. For example, to prepare for the 2009-2010 academic year, the applied mathematics faculty, in collaboration with the School of Natural Sciences' Dean's Office, planned their staff lecturer hiring based the projected budget. Due to the poor financial landscape in California, the total number of staff lecturers were cut overall. However, as the academic year approached, the applied mathematics faculty found that the number of courses and sections needed for the incoming class of students far exceeded the capacity of the hired instructional staff. The applied mathematics faculty had to request the resources to hire more staff lecturers, seek them out, interview and hire them. Under this short time-scale, the applied mathematics faculty were able to hire a few more staff lecturers to increase the teaching capacity, but not enough to meet all of the student demand. There remain students still who are not able to take the lower division mathematics courses that they need this year. It is critical to the success of this program that the UC Merced administration work with the applied mathematics faculty to formulate a clear plan for resource allocation. The current situation causes an enormous amount of unnecessary stress on faculty, staff and students. It is simply unacceptable to continue in this manner any longer.

Some alternative strategies for rectifying these opposing forces include increasing class sizes and increasing the teaching load. The applied mathematics faculty have made some concessions on these two items. The class sizes have increased and graduate student teaching assistants teach more sections, for example. However, the applied mathematics faculty feel that this is a very poor solution to this problem. Both staff lecturers and graduate student teaching assistants have a set workload which cannot be exceeded. Thus, increasing class sizes and having an individual teach more sections can only lead to poorer quality of instruction which, in turn, will lead to student dissatifaction – both of which are completely counterproductive to the mission of this program. The applied mathematics faculty have already experienced this situation in their first effort to deliver Math 5: Pre-calculus (see Section 11.2.1). The applied mathematics faculty will need to work with the School of Natural Sciences and UC Merced administration to address this ever-growing problem. Maintaining the status quo is no longer going to be acceptable. Doing so undermines the quality of education that the applied mathematics faculty are dedicated to maintain for this university.

6.3 Plans to Shift Programmatic Emphasis or Learning Outcomes

At present, there are no immediate plans to shift the programmatic emphasis or learning outcomes of the Applied Mathematical Sciences program. Instead, the applied mathematics faculty will take the next several years to continue to assess the program learning outcomes throughout its curriculum to identify and discuss the effectiveness of the curriculum. The applied mathematics faculty anticipates forming a plan for any programmatic shifts or changes to learning outcomes by the time of its next review.

6.4 Approaches to Developing New Strengths

The most important way to develop new strengths for the Applied Mathematical Sciences program is hiring new faculty. New faculty fortify expertise in the core of applied mathematics while bringing new research areas to the program. These new research areas of expertise allow for the development of new courses for students. New faculty bring also a new perspective on how to enable students to achieve the goals of this

program. As mentioned above, the applied mathematics faculty plan to hire one new faculty each year to a build-out of approximately twenty applied mathematics faculty.

6.5 Plans to Merge or Subdivide to Achieve Programmatic Focus

There are no immediate plans for merging or subdividing to achieve programmatic focus. At present, the eight senate faculty who comprise the applied mathematics faculty work autonomously, for the most part, in managing this program. The applied mathematics faculty work currently with other faculty in the School of Natural Sciences on issues of academic personnel and strategic planning. In the very near future, the applied mathematics faculty will seek to form their own academic "unit."

7 Faculty

The entire applied mathematics faculty is listed below

- Harish S. Bhat (began in July, 2008)
- François Blanchette (began in July, 2006)
- Boaz Ilan (began in July, 2005)
- Arnold D. Kim (began in July, 2004)
- Lei, Yue (began in July, 2009)
- Roummel Marcia (began in July, 2009)
- Michael Sprague (began in July, 2005)
- Mayya Tokman (began in July, 2005)

7.1 Information on Markers of Quality

Markers of quality are listed below for each of the faculty members.

- Harish Bhat
  - 2005 First Place at the Stanford-Berkeley-Caltech Innovators Challenge, in collaboration with E. Afshari and A. Hajimiri.
  - 2005 Student Paper Prize and Travel Award for 2005 IMACS International Conference on Nonlinear Evolution Equations and Wave Phenomena, UGA.
  - 2000-2003 National Science Foundation Graduate Research Fellowship, Mathematical Sciences.
  - NSF Grant: Collaborative Research: Algorithms for Simulation and Design of Analog VLSI Lattices (DMS-0913048),
- François Blanchette
  - 2005 MRSEC Fellow, University of Chicago.

- 1999-2002 Canadian National Science and Engineering Research Council Post-Graduate Scholarship, type A (1999), type B (2001).
- 1999 MIT Presidential Fellowship.
- NSF Grant: Simulations of surface tension driven flows and interactions between fluid flow and solid particles (DMS-0808129).

- Boaz Ilan
  - 1990 Shai Blaiman Contest in Mathematics and Computer Science V Second place (national), Israel
  - 1999 Vladimir Schreiber Award for Excellence in M.Sc. Studies in Mathematics, Tel Aviv University, Tel Aviv, Israel
  - 2001 Marejn Foundation Award for Excellence in Ph.D. Studies in Exact Sciences, Tel Aviv University, Tel Aviv, Israel
  - 2002 George S. Wise Award for Excellence in Ph.D. Studies in Mathematics, Tel Aviv University, Tel Aviv, Israel
  - NSF Shared Instrument Grant: MRI: Acquisition of Composite Femtosecond Lasing Systems for Broadband Non-linear Static and Dynamic Optical Analysis of Organic and Semiconducting Systems (DMR-0821771)
  - NSF Grant: Luminescent Solar Concentrators Based on Semiconductor Nanorods (CHE 0934615).

- Arnold D. Kim
  - 1999 Department of Applied Mathematics, University of Washington Award for Teaching and Service
  - 1999 NSF VIGRE Research Associate, Department of Applied Mathematics, University of Washington Award
  - NSF Postdoctoral Fellowship, Ultra-short optical pulse propagation in random media (DMS-0071578)
  - DOE Grant: A Center for Computational Biology, US Department of Energy (Co-PI and Deputy Director)
  - NSF Grant: Mathematical investigation of light propagation in tissues for physiological monitoring and tissue imaging (DMS-0504858)
  - Specer Foundation Grant: Forum for Excellence in Higher Education: Improving Writing and Mathematics at UC Merced by Developing an Undergraduate Research Journal and Redeveloping Pre-Calculus
  - NSF Grant: Focused Research Group on Inverse Problems in Transport Theory (DMS-0553569)
  - NSF Grant: Inverse Scattering Theory for the Radiative Transport Equation (EEC-0616228)
  - NSF Grant: Direct and inverse problems for reflectance optical tomography and spectroscopy in layered tissues (DMS-0806039)

- Roummel Marcia

  - NSF Grant: Second-order methods for large-scale optimization in compressed sensing (DMS-0811062)

- Michael Sprague
  - Fall 2001 Outstanding TA Award, Univ. of Colorado at Boulder, Mechanical Engineering
  - 2003 Young Investigator Fellowship, 7th US National Congress on Computational Mechanics
  - 2003 - 2005 NSF VIGRE Postdoctoral Scholar
  - 2007 Multi-scale modeling and computation of convective geophysical turbulence, NASA National Leadership Computing System (NLCS), 1.25 million hours of CPU time on the 2048-processor Columbia supercomputer to perform numerical simulations for rotationally constrained convection.
  - 2006-2008 Hydrodynamics control by highly accurate numerical simulation and modelling of the filtering processes and membrane separation, 8000 euro/year for three years to support travel of French researchers to collaborate with M. Sprague and R. Lueptow in the USA.

- Mayya Tokman
  - 2005-2006 AAAS Policy Fellowship
  - 2002 Marshall N. Rosenbluth Outstanding Doctoral Thesis Award, APS.
  - 2001 W. Carey Prize for Outstanding Thesis in Applied Mathematics, Caltech.
  - 2001 The Frederick A. Howes Scholar in Computational Science Award, DOE CSGF Program.
  - NSF grant: Projection Methods for Multiscale Problems in Plasma Physics and Applications (DMS-0317511)

7.2 Faculty Contributions

Each and all of the applied mathematics faculty have been actively involved in curriculum development, pedagogical practices and several other teaching and learning-related matters. Drs. Kim and Tokman put together the initial proposal for the Applied Mathematical Sciences major. Ever since that initial proposal, each applied mathematics faculty member has been providing valuable contributions to the program including making changes to the core curriculum and developing new courses.

In fact, the applied mathematics faculty have developed two graduate courses so that graduate student teaching assistants can develop their teaching skills and learn the values of teaching undergraduates well. These courses were developed originally by Dr. Sprague in collaboration with Dr. Laura Martin in the Center for Research in Teaching Excellence. Since that initial development, Dr. Lei has been teaching these course and leading their on-going development. These two courses are described below.

- *Math 201: Teaching and Learning in the Sciences* – Students will be introduced to 'scientific teaching' - an approach to teaching science that uses many of the same skills applied in research. Topics will include how people learn, active learning, designing, organizing and facilitating teachable units, classroom management, diversity in the classroom and assessment design.

- *Math 399: University Teaching* – This course is centered on a student's classroom experiences as a Teaching Assistant in an undergraduate Applied Mathematics course. Provides a faculty-directed opportunity to implement teaching practices presented in the course Teaching and Learning in the Sciences. Course will involve video-taping of teaching, peer review, and weekly meetings with faculty.

The applied mathematics faculty are also involved actively in general education. The course, *Math 91: General Topics in Applied Mathematics* developed by Dr. Blanchette, is a sophomore seminar course. It gives an introduction to a variety of concepts useful in applied mathematics including floating point arithmetic, methods of proofs, random walks, stereographic projections, transforms, etc. It is meant to give students an opportunity to learn about the Applied Mathematical Sciences major.

In addition, Dr. Kim has participated in the general education course, *Core 1: The World at Home: Planning for the Future in a Complex World*. Each and every semester since UC Merced began, Dr. Kim has given a lecture entitled, "The Language of Mathematics." This lecture introduces students to the general concepts of mathematical problem solving, and compares its aesthetics to those in art and music.

7.3 Student Evaluations Data

In Table 2, we present a summary of the student evaluation data for courses taught by ladder-rank applied mathematics faculty. In particular, we give the average over all student ratings for the category of "Overall effectiveness of this instructor." The scores are given on a scale of 0.00 to 7.00 with 7.00 denoting the highest rating. The Excel spreadsheets contained in the file `Student Evaluations Data.xlsx` gives more details.

All of the student evaluations data are not readily available. For example, all student evaluation data for the Fall 2006 semester was lost due to a stolen computer. Moreover, the School of Natural Sciences has been steadily improving its collection of student evaluations over the past several years. Nonetheless, we are able to draw several conclusions based on the data that are available.

Table 2 show a consistent excellence in instruction. Across lower division courses, upper division courses and graduate courses, the applied mathematics faculty have demonstrated clearly that they have been effective teachers. The mean score of those listed in Table 2 is 6.49 with a standard deviation of 0.49. The inaccuracies of student evaluation ratings notwithstanding, these data reflect the applied mathematics faculty's dedication to quality of instruction.

8 Students

8.1 Retention, Time-to-degree and GPA Data

The data that exist for retention, time-to-degree and GPA are contained in Table H of the file `UCM Academic Program Review Data - Math.xlsx` prepared by the Department of Institutional Planning and Analysis.

At present, there are not many meaningful statistics to draw due to the infancy of this program. There are several issues that need to be explained with the student success information. First, in the case of Applied Math, there were no undergraduate majors until Fall 2006. Hence, there are no data for the 2005-06 academic year. Second, the retention/graduation rate data are for first-time freshman students who initially declared Applied Math as their major; this data does not include students who switched into Applied Math after their initial cohort year. Since there were no Applied Mathematical Sciences majors in Fall 2005, there is not a cohort yet that has reached the 4 year graduation milestone. Therefore, we are not able to report any meaningful graduation rates yet.

Table 2: Summary of student evaluation ratings for course taught by applied mathematics faculty.

Semester	Course	Rating (out of 7.00)
Fall 05	Math 21	6.20
	Math 22	6.92
Spring 06	Math 22	6.90
	Math 24	6.31
	Math 32	6.80
Fall 06	*no data available*	
Spring 07	Math 23	6.17
	Math 24	6.56
	Math 30	6.53
	Math 232	7.00
	Math 223	6.80
	Math 291	7.00
Fall 07	Math 21	6.59
	Math 121	6.71
	Math 131	6.65
	Math 221	6.50
	Math 298	7.00
	Math 399	6.71
Spring 08	Math 24	6.82
	Math 122	6.33
	Math 222	6.86
Fall 08	Math 121	6.90
	Math 131	5.59
	Math 141	6.77
	Math 221	5.60
	Math 232	6.75
	Math 298	6.60
Spring 09	Math 21	6.32
	Math 22	6.73
	Math 23	6.65
	Math 91	6.50
	Math 122	6.82
	Math 142	5.46
	Math 223	6.50
Fall 09	Math 21	6.31
	Math 32	5.79
	Math 121	6.53
	Math 131	6.14
	Math 141	6.50
	Math 221	4.64
	Math 231	7.00
	Math 298	6.78

As part of the mission of UC Merced to be a student-centered research university, the applied mathematics faculty have supervised several undergraduate students in research. Below is a list of these undergraduate research projects.

- Mr. Paul Tranquilli worked with Professor Kim on a project involving the numerical solution of a variable coefficient Fokker-Planck equation. This research resulted in the publication: A. D. Kim and P. Tranquilli, "Numerical solution of a boundary value problem for the Fokker-Planck equation with variable coefficients," *Journal of Quantitative Spectroscopy and Radiative Transfer* **109**, 727-740 (2007).

- Ms. Julia Clark worked with Professor Kim on a project involving the multiple scattering of polarized light. This research resulted in the publication: J. Clark, P. González-Rodríguez and A. D. Kim, "Using polarization to find a source in a turbid medium," *Journal of the Optical Society of America A* **26**, 1129-1138 (2009).

- Ms. Sydney Montroy and Mr. William Douandju have been working with Professor Blanchette on a project to study the potential of settling particles, typically sediments, to act as heat carriers. This research resulted in the submitting of a paper to the journal *Physics of Fluids* which is currently under review.

- Ms. Maureen Long, Mr. Anthony Grimes, and Mr. Brent Rich worked with Professor Sprague on a project to study a microfluidic mixing device. This research resulted in the publication: M. Long, M.A. Sprague, A.A. Grimes, B.D. Rich, and M. Khine, "A simple threedimensional vortex micromixer," *Applied Physics Letters* **94**, 133501.

- Mr. Paul Tranquilli has been working with Professor Tokman on a project to develop efficient and safe wood burning stoves that address the global need to reduce indoor air pollution – one of the top 10 global health risks, according to the World Health Organization. Recently, Mr. Karl Loepker and Mr. Mark Bailey have joined Mr. Tranquilli and Professor Tokman on this project.

8.2 Student Profiles

Table 3 shows a summary of Table G of the file `UCM Academic Program Review Data - Math.xlsx` prepared by the Department of Institutional Planning and Analysis. These data reflect the broad diversity of the Applied Mathematical Sciences students. In particular, it is important to acknowledge that 60% of our majors at Fall Semester, 2009 are first generation college students. Moreover, as of Fall Semester, 2009, approximately 40% of our majors identify themselves as Hispanic.

That the female-to-male ratio among Applied Mathematical Sciences majors is approximately 3/7 is typical nationally. However, the applied mathematics faculty would like to work actively to increase the number of female Applied Mathematical Sciences students in the future. As a result, the applied mathematics faculty will develop and implement strategies to attract more women students to the Applied Mathematical Sciences major.

8.3 Comparison to National Norms

Due to the limited data that are available presently (see our explanation in Section 8.1), we have not been able to perform a comprehensive comparison of our students' achievements to national norms. Nonetheless,

Table 3: A summary of Applied Mathematical Sciences student profiles.

		Fall 05	Fall 06	Fall 07	Fall 08	Fall 09
Total Majors		N/A	6	23	38	57
Gender	Female	N/A	33.3%	26.1%	34.2%	26.3%
	Male	N/A	66.7%	73.9%	65.8%	73.7%
Race/Ethnicity	Black/African-American	N/A	16.7%	4.3%	7.9%	7.0%
	Asian/Pacific Islander	N/A	16.7%	43.5%	28.9%	19.3%
	Native American Indian	N/A	0.0%	0.0%	0.0%	0.0%
	Hispanic	N/A	16.7%	13.0%	18.4%	40.4%
	White	N/A	33.3%	34.8%	31.6%	24.6%
	International	N/A	0.0%	0.0%	7.9%	3.5%
	Unknown	N/A	16.7%	4.3%	5.3%	5.3%
First Generation College		N/A	33.3%	39.1%	44.7%	59.6%
First Language	English Only	N/A	33.3%	26.1%	10.5%	10.5%
	English & Other Language	N/A	0.0%	8.7%	10.5%	14.0%
	Non-English Language Only	N/A	0.0%	17.4%	10.5%	14.0%
	Unknown	N/A	66.7%	47.8%	68.4%	61.4%

we have attempted to draw some early comparisons of Applied Mathematical Sciences students to those across the entire UC Merced campus.

Table 4 shows some example comparisons between averages of the Applied Mathematical Sciences students and averages of all UC Merced students (including the Applied Mathematical Sciences students). These examples are part of a more detailed analysis given in Table F of the file `UCM Academic Program Review Data - Math.xlsx` prepared by the Department of Institutional Planning and Analysis.

Table 4: A comparison of Applied Mathematical Sciences students to those across the entire UC Merced campus.

		Fall 2005	Fall 2006	Fall 2007	Fall 2008	Fall 2009
Ave HS GPA	UCM Students	3.4	3.46	3.47	3.42	3.44
	AMS Students	N/A	3.24	3.47	3.47	3.59
SAT Total	UCM Students	1071	1552	1560	1544	1538
	AMS Students	N/A	1425	1765	1598	1519
SAT Verbal	UCM Students	520	505	511	507	504
	AMS Students	N/A	410	568	523	480
SAT Math	UCM Students	551	542	542	535	530
	AMS Students	N/A	585	657	573	562
SAT Writing	UCM Students	N/A	504	508	502	503
	AMS Students	N/A	430	541	501	477

The data shown in Table 4 indicates that the students majoring in Applied Mathematical Sciences have similar academic backgrounds to those across the entire UC Merced campus except for SAT Math average scores. For that case, the Applied Mathematical Sciences students have consistently a higher average score

than those across the entire UC Merced campus.

It is tempting to draw more conclusions from this comparison or attempt to make more, but doing so would be subject to objection. At this early stage of the program as well as the entire UC Merced campus, we do not have sufficiently rich data to draw more meaningful conclusions.

8.4 Teaching Evaluations and Assessment

Table 5 shows a summary of student teaching evaluations data. In particular, we have computed an average score over each semester for which we have data in the following three categories:

1. *This class is well organized.*
2. *The instructor displays enthusiam for the subject matter.*
3. *Overall effectiveness of this instructor.*

We computed these averages over all mathematics course for which we have this data. Thus, these averages include classes taught by staff lecturers serving as both primary lecturer and teaching assistant.

The scores listed in Table 5 are given on a scale of 0.00 to 7.00 with 7.00 denoting the highest rating. The Excel spreadsheets contained in the file `Student Evaluations Data.xlsx` gives more details.

Table 5: A summary of averaged student evaluation ratings.

Fall 05	Spring 06	Fall 06	Spring 07	Fall 07	Spring 08	Fall 08	Spring 09	Fall 09
6.13	6.42	No Data	6.32	6.34	6.31	6.32	6.27	6.25

From this data, we have found that the instruction of the Applied Mathematical Sciences program to be consistently good to excellent. The lowest average of 6.13 for Fall Semester, 2005 can be attributed largely to the Math 5 class. This class was given in a large lecture format and was largely unpopular with students. Since that semester, we have changed our method for teaching this course (see Section 11.1.2 for more details). Ever since that time, we have seen consistenly high average student evaluation ratings.

The applied mathematics faculty are dedicated to providing instruction to our students of the highest quality. We are continually striving to improve our teaching so that our students can experience a truly positive learning experience. The data we have collected thus far indicates that we are successful, but we will continue to seek ways to improve both the measurement of our teaching quality as well as our teaching quality, itself.

9 Diversity

The Applied Mathematical Science program has a strong committment to diversity in its students. The data shown in Table 3 shows that this program has been successful in recruiting students from a diversity of backgrounds. The applied mathematics faculty are continually developing methods to encourage students from a diversity of background to pursue the Applied Mathematical Sciences major. One example of this effort includes a special breakfast meeting during a campus recruiting session for perspective students and families. This meeting included a seminar by Dr. Mark Johnson, who has had a variety of jobs as a professional mathematician including Yahoo!, Netflix and as an analyst for the St. Louis Cardinals baseball team. Because many of the UC Merced students are first generation students, the applied mathematics faculty feel

it is important to program events for entire families. Moreover, an important part of recruiting students is showing them the broad variety of job opportunities that students graduating with a B.S. in Applied Mathematical Sciences have. Another recruiting event involved a seminar talk by Dr. Helen Moore who has held research positions at Genetech as well as a specialist in diversity at the American Institute of Mathematics. Dr. Moore spoke of numerous opportunities for young female mathematicians in industry. In the near future, the applied mathematics faculty plans to hold more of these recruiting events to encourage all students to pursue a major in Applied Mathematical Sciences.

The Applied Mathematical Science program has a strong committment to diversity in its faculty. For recruitments of new faculty, the applied mathematics faculty adhere to the guidelines set forth by the faculty of the School of Natural Sciences. In particular, a search committee puts together a detailed hiring plan. Included in this plan are specific strategies for obtaining a diverse applicant pool. Some example strategies that the applied mathematics faculty have used include the following.

- The job advertisment has an explicit statement that encourages women and underrepresented minorities to apply to the position.
- In addition to posting advertisements in appropriate professional society job lists, the applied mathematics faculty posts the advertisement to the Association for Women in Mathematics (AWM), Professional Opportunities and the National Association for Mathematicians (NAM) and the Society for Advancing Hispanics/Chicanos and Native Americans in Science (SACNAS).
- The search committee chair send emails with the job advertisement attached to Dr. Ricardo Cortez who represents the Summer Institute in Mathematics for Undergraduates, Dr. Bill Massey who represents the Conference for African-American Researchers in the Mathematical Sciences, and Dr. Carlos Castillo-Chavez who represents the Mathematical and Theoretical Biology Institute. All of these three research programs are for young mathematicans from diverse backgrounds. In this email, the search committee chair requests that the representatives distribute the email to lists of mathematicians who have participated in mathematics programs that emphasize diversity.

Near the close of the faculty candidate search, the list of applicants and their diversity data are compared to national standards for diversity and then reviewed by the Dean of the School of Natural Sciences. If the candidate pool is not sufficiently diverse, the search is extended for the purpose of obtaining more candidates that lead to a sufficiently diverse applicant pool. Prior to bringing out candidates to interview, the search committee chair fills out the "Affirmative Action Summary" form[10] (UCM-AP22). The search committee takes special care to maintain diversity across its rankings of candidates from the original candidate pool up to the interview list. In fact, the results of the candidate rankings must be approved by the Dean of the School of Natural Sciences prior to brining any candidate out to interview.

10 Alumni

There were 7 B.S. degrees in Applied Mathematical Sciences awarded in the 2008-09 academic year. Here is what we know of our graduates.

- Ms. Alaena Alilin is a graduate student in Applied Mathematics at UC Merced.
- Mr. Jimmy Hiep Nguyen is a DVT Engineer at Juniper Networks in Sunnyvale, CA.

[10] see http://academicpersonnel.ucmerced.edu/pdf/AP22_Aff%20Action%20Summary.xls

- Ms. Mary Panos is a Level 7 Associate at In-N-Out Burgers in Merced, CA.
- Ms. PeiChen Shu is an R&D Engineer at Landmark Technology in San Jose, CA.
- Mr. William St. Claire is a graduate student in Cognitive Sciences at UC Merced.
- Mr. Paul Tranquilli is a graduate student in Applied Mathematics at UC Merced.
- Ms. Veronica Young is a graduate student in the Department of Biostatistics at George Washington University after a student fellowship in the Research Alliance in Math and Science at Oak Ridge National Laboratory.

The degree data is not available yet for the 2009-10 academic year. That data will not be available until December, 2010. However, there have been 5 applications submitted for Spring 2010 graduation.

11 Status Report

Section 4 gives a historical account of the Applied Mathematical Sciences program ever since its first proposal to the School of Natural Sciences in January, 2005. Section 4 goes on to discuss the name change from "Mathematical Sciences" to "Applied Mathematical Sciences."

11.1 Description of Programmatic Changes to Date

Section 2.1 gives a list of programmatic changes that have occurred thus far. Below, we describe each these changes in detail.

11.1.1 Student Placement

At the beginning of the 2007-2008 academic year, the applied mathematics faculty hired Ms. Cheryl Hedges as the Math Coordinator. One of the first issues that Ms. Hedges attempted to address was placing incoming students in our lower division mathematics courses correctly. A survey of the educational reserach done on this issue shows that student placement is an inherently challenging issue, but one of critical importance for obtaining student success, especially for underrepresented minority students.

For our inaugural year, the applied mathematics faculty used the "Calculus Readiness" test written by the Mathematics Diagnostic Testing Project[11]. Several other UC and CSU campuses use these tests for their placement. At that time, the test was a "pencil and paper" multiple-choice test only[12]. The applied mathematics faculty made decisions on student placement based on the test scores using results from other institutions that used this test. Essentially, there is a single cut-off score. If students scored more points than this cut-off, they were advised to take Calculus I (Math 21). Otherwise, students were advised to take Pre-calculus (Math 5). Incoming students took this placement test during student orientations the summer before they began their studies at University of California, Merced.

Due to the inconvenience of this testing environment to students, the applied mathematics sought an online placement test. For the next several years, the applied mathematics faculty used the Maplesoft-MAA Placement Test Suite[13]. These tests were designed by a panel of university mathematics teachers

[11] `http://mdtp.ucsd.edu`

[12] The MDTP has recently developed an online test that the applied mathematics faculty may evaluate for future use

[13] `http://www.maplesoft.com/products/placement/maa.aspx`

and approved by the Mathematical Association of America (MAA). However, the test did not come with recommendations on placement based on test scores. The applied mathematics faculty set cut-off scores for this test based their evaluation of the test and their opinion on expectations for student preparedness.

By performing an analysis on former placement scores, Ms. Hedges worked out several scenarios for different placement score cut-offs. Included in this analysis are predictions for distributions of enrollments as well as student achievement based on final course grades. After presenting this analysis to the applied mathematics faculty, Ms. Hedges led a discussion that led to our current cut-off score. In the end, this data analysis gave the applied mathematics faculty the confidence in their decision.

The applied mathematics faculty have continued to monitor the results of the placement cut-off score to make sure that it continues to be effective for placement. For the 2008-2009 academic year, the applied mathematics faculty have migrated to an open-source solution called WeBWorK[14] to administer the placement test. The faculty worked together to write this test based largely on the Maplesoft-MAA test. The challenges in placing students into mathematics courses correctly are ongoing. Nonetheless, it is clear from these initial experiences that the applied mathematics faculty makes decisions best using an analysis of the student data available.

11.1.2 Restructuring Pre-calculus

In Fall 2005, the campus' inaugural semester, roughly 140 students placed into Calculus I or II, versus approximately 400 who placed into pre-calculus. The pre-calculus course, Math 5, initially followed the model of most large universities: students met in a large lecture (200 students/class) several times a week, and also met in small discussion sections (25 students each) with a TA. We adopted Treisman workshop-style discussion sections, so students spent a majority of their time working on problems in section, rather than watching the TA solve problems. We chose as a text the #1-seller for this course that several other UC campuses use.

Early in the semester, however, we began to detect real difficulties: student performance on the first midterm exam was dismal overall; the *esprit de corps* of the class was poor within just a few weeks; and students and teachers alike seemed frustrated by the course, but were unable to figure out how to make dramatic improvements. Among other challenges, everyone in the course felt that there was a lack of coherence: the text leapt from one topic to another, initially moving, for example, from absolute values one day to solving equations the next, to rectangular coordinates the next, and so on. Students felt like they were not making progress in building deep understanding of any particular topic, and felt instead like they were simply revisiting material they had seen in earlier math classes, only at a much faster pace. As one colleague stated: "How can they be motivated when the reward they perceive for surviving this class is more of the same in future semesters?" Of course, the students' perceptions were inaccurate, since the calculus courses offer much more intellectual stimulation than the inaugural pre-calculus course, but the students had no way of knowing that.

While we predicted a high failure rate for students' final grades, we were unprepared for the ultimate statistic: over 50% of the students did not pass the class. (This number does not account for students who dropped the course sometime during the semester.) Worse, we all had concerns about students who passed with a low-C: while they may have "passed," we did not feel that they are well prepared for future courses. This was deemed by all as a simply unacceptable outcome.

During the middle of the semester, we began to search for a different model of teaching this class, looking for best practices at other large universities. We identified an outstanding one at the University of

[14] `http://webwork.maa.org/wiki/Main_Page`

Michigan, which has a long track record of helping large numbers of students excel through their introductory courses. After corresponding and visiting with the University of Michigan faculty in charge of the program, the applied mathematics faculty decided to implement Michigan's model for the Spring semester. This adoption represents a huge shift for this large course in which we have responded to the students' needs in a very short time.

Some characteristic key features of the new course include:

- *Elimination of large lecture:* Students now meet solely in small classes of 25-30 students. Homework, tests, and final grades are handled by central course coordinators, but each instructor is in charge of his or her students' learning. Among other benefits, we aim to form "learning communities" within these small classes.

- *Active learning:* Students learn best when they themselves are actively engaged in the material, making sense of things for themselves rather than watching someone else do math. Lecturing is minimized in this course; instead, students are expected to read the text ahead of time, and the instructor then gives mini-lectures interspersed with students working on challenging problems in groups for the bulk of the time.

- *Use of a different text:* We now use the text, *Functions Modeling Change: A Preparation for Calculus*. This text has a clear theme – functions – which immediately gives the course coherence. Furthermore, it is written with the expectation that students have seen all of the basic skills necessary in earlier classes; the focus here instead is on using those skills to treat mathematically interesting scenarios. There is a great deal of real-world data in the problems, and consistently functions are examined symbolically, numerically, graphically, and verbally (the so-called "Rule of Four.")

Overall, the applied mathematics faculty have found this new pre-calculus course to be more effective in enabling students to learn the skills they need to succeed in calculus. The small class sizes allow for more personalized attention to student needs. Moreover, these managable size allow for effective active learning modules in class. Although student success attributed to these items alone are difficult to measure directly, the applied mathematics faculty believes firmly in this restructured pre-calculus course.

However, there are some recent developments that require a renewed attention to pre-calculus at UC Merced. We are finding that as the enrollments grow, the number of students who need pre-calculus is growing beyond our capacity to teach students using this structure. We have already limited enrollments by prioritizing students by the needs of their declared majors. Moreover, we have found that there is a significant fraction of students in pre-calculus whose mathematical preparedness is lacking for success in this course. This fact is problematic because the applied mathematics faculty is restricted from developing courses below this level since those courses would not be university-level mathematics courses.

One conclusion that seems to be drawing near is that the growing number of students requiring mathematics training at the pre-calculus level is beyond the capacity of what the applied mathematics faculty can do with the resources available to them. Because this item affects not only the School of Natural Sciences, but the entire university (these students are very rarely Applied Mathematical Sciences majors and are, in fact, other majors in all three schools), the applied mathematics faculty believes the university needs to consider this issue and take a more active role in addressing it. The applied mathematics faculty have called already for a new structure for addressing the needs of students requiring basic mathematics training. The applied mathematics faculty can no longer meet the needs of this important population of students by themselves.

11.1.3 Calculus Textbook Adoption

The applied mathematics faculty decided early on to adopt a single textbook that would serve all of the calculus courses: Math 21, 22, 23 and 30. The original text was by Hughes-Hallet *et al*. For several reasons, the applied mathematics faculty and the students in these classes voiced concerns over this particular text. To respond to these concerns, the applied mathematics faculty met to evaluate several other textbooks after the Spring Semester of the 2006-2007 academic year. After several discussions, the applied mathematics faculty decided to use the text by Stewart. The applied mathemaics faculty felt that this text aligns better with the goals and objectives of the calculus courses. The applied mathematics faculty have found that both students and faculty enjoy the use of this text. It has been the text for Math 21, 22, 23 and 30 ever since.

11.1.4 New Calculcus Course Sequence

Dr. Lei, Yue, who serves currently as the applied mathematics faculty member who oversees the calculus courses expressed an observation about our calculus students. Subsequently, Ms. Hedges performed an analysis of the student data which helped to confirm a consistent and significant divide between two major groups of students:

1. Students needing at most two semesters of single-variable calculus;
2. Students requiring vector calculus, linear algebra and differential equations.

These two groups of students have very different motivations and objectives for taking calculus due largely to their specific academic goals.

The applied mathematics faculty have found that reaching both groups of students effectively and helping them to achieve their educational goals in the existing Math 21 and 22 courses is becoming more and more challenging. For example, to focus on the needs of the first group of students to develop and practice their problem-solving skills needed to understand the fundamental concepts in calculus requires time away from some of the technical details that are needed by students in the second group. On the other hand, preparing students in Math 21 and 22 for the material in Math 23 and 24 only serves the proportion of students who will go on to take those courses.

To address this problem, we are proposing this year a new, two semester calculus sequence comprised of the courses Math 11: Calculus I and Math 12: Calculus II. These courses are under review currently. These two courses are designed to meet the needs of the first group of students listed above. We will remove the existing course, Math 30: Calculus II for Biological Sciences since we will be replacing that course with Math 12. Consequently, Math 21 and Math 22 will be tailored to meet the needs of the second group of students listed above. We are tentatively going to change the name of Math 21/22 to Calculus I/II for Physical Sciences and Engineering, respectively, since these courses serve those particular majors. Thus, we propose that those majors requiring at most two semesters of calculus take Math 11 and 12 and those majors requiring more than two semesters of calculus take Math 21 and 22.

11.1.5 Reorganizing the Core Curriculum

After our first cohort of Applied Mathematical Sciences majors went through our core curriculum of applied mathematics courses, the applied mathematics faculty determined that this core required some reorganizing. In particular, with respect to PLO 1, the applied mathematics faculty found that students were having difficulty making the transition to rigor required for upper level mathematics courses focusing on analytical methods. Students were not meeting the applied mathematics faculty's expectations. Through individual

discussions with students, the applied mathematics faculty determined that students felt that the difficulty in the content changed too abruptly from the lower division courses to the upper division courses.

The applied mathematics faculty meet in the summer of 2008 to discuss this matter. From this discussion, the applied mathematics faculty have decided to reorganize their upper division core courses that focus on analytical solutions methods. In particular, the applied mathematics faculty reorganized the content across the entire core so that students could develop their analytical problem-solving skills more gradually and in a more naturally progression.

In particular, the applied mathematics faculty paid more attention to the transition that students make from the lower division Math 24 course to the current Math 121 course. The new course sequence, which is under review currently, eliminates Math 121 and replaces it with a new course, Math 125 and eliminates Math 142 and replaces it with a new course, Math 126. The sequence of Math 24, Math 125 and Math 126 gives students a three-course sequence in which students build and develop skills for solving ordinary and partial differential equations. By having this three course sequence, students can build smoothly and continually their analytical problem-solving skills rather than having three disjoint courses. Included with these changes are pre-requisite changes to ensure this smooth and continuous progression through these three courses that has an appropriate inclusion of material learned from those pre-requisite courses.

11.1.6 Capstone Modeling Course

As part of the development of the program learning outcomes, the applied mathematics faculty constructed a map of the current courses that make up the Applied Mathematical Sciences core curriculum. For each course in the core curriculum, the applied mathematics faculty examined each of the five program learning outcomes listed above and identified if this course provides an introduction (I), develop (D) or mastery (M) level appropriate for graduation. The resulting map is given in tn Table 6 below. This map provides a way to visualize the intellectual development of students as they progress through this curriculum.

Table 6: PLO map of the current courses in the Applied Mathematical Sciences core.

Course	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5
Math 5	I			I	I
Math 15		I		I	
Math 18	I	I	I		I
Math 21	I		I	I	I
Math 22	I	I	I	I	I
Math 23	D		I	I	I
Math 24	D		I	I	D
Math 30	I	I		I	I
Math 32	D	I	I		I
Math 121	M		D	D	M
Math 122	M		D	D	M
Math 131	M	D	D	D	M
Math 132	M	M	D	D	M
Math 141	M		D	M	M
Math 142	M		D	M	M

A quick survey of the map in Table 6 shows that there is a deficiency in developing mastery for PLO 3. Among all others, PLO 3 requires the most academic maturity since students must be well-acquanted with the other PLO's of this program as well as the PLO's of other programs to which they synthesize and apply all of their skills. By participating in the excercise of creating this course map, the applied mathematics faculty decided in the Summer of 2008 to make this issue a priority.

To address PLO 3 at the mastery level, the applied mathematics faculty will develop a capstone course in mathematical modeling. This course will serve several functions. One such function is to provide a unique experience for the Applied Mathematical Sciences majors that include a series of activities designed to enhance their knowledge and appreciation of applied mathematics while preparing them for entry into a graduate program or placement in government, industry and business. Other functions of this capstone modeling course include avenues to assess the program through projects, presentations, and research.

We plan to develop a prototype for this course during Summer 2010. This development will include a sample of the current Applied Mathematical Sciences majors. These students will survey different modeling problems and help choose which problems may be relevant and interesting to future students. By Fall Semester 2012, we plan to deliver this capstone course.

11.2 Current Limitations on Assessment

The Applied Mathematical Sciences program has been operating since Fall Semester, 2006. Thus, the main limitation on assessment has been the limited data available to assess certain aspects of the program, *e.g.* there are very few alumni from this program. The applied mathematics faculty is dedicated to taking the next several years to establish its culture for assessment as more student data emerges.

To conduct future assessments and carry out the plans above, the Applied Mathematical Sciences program will require several resources. Several of these resource needs are under consideration or under development within the School of Natural Sciences, the Center for Research on Teaching Excellence and Institutional Planning and Analysis. Other resource have not been addressed adequately by this university.

A critical component of all future assessments is evidence collecting. For the past several years, the applied mathematics faculty benefitted from the work of Ms. Cheryl Hedges, who acted as Math Coordinator. Ms. Hedges collected student data from all of the lower division mathematics courses and produced a summary analysis of that data[15]. The applied mathematics faculty used that data each semester to conduct meetings and make plans for the following semester. This data and analysis was critical for the applied mathematics faculty to consider changes to the curriculum as well as in designing more formal assessments to investigate concerns more deeply. Unfortunately, Ms. Hedges moved on from that position and it remains unfilled due to the current fiscal situation. However, School of Natural Sciences' Dean Pallavicini saw the need for this kind of data collection and analysis for all of the programs within the School of Natural Sciences. Consequently, she has been allocated staff support to help the programs within the school, including Applied Mathematical Sciences, continue their routine data collection and analysis.

An important area where this data collection and analysis will be crucial is for the lower division service mathematics courses, especially with the ever-growing number of students needing Math 5: Pre-calculus and even more fundamental mathematics skill building. The implications of assessments made by the Applied Mathematical Sciences program on these lower division courses are far-reaching in that they affect several other programs on campus. As a result, these assessments will have to be done in cooperation and coordination with those other programs. As we have mentioned in Section 2.3, the applied mathematics

[15] See the files discussed in Section 6 of the Data Section for the Self-Review of the Applied Mathematical Sciences Program at University of California, Merced.

faculty plans to form a "lower division mathematics summit" to gather all of the programs to whom these courses serve. We hope that our colleagues in other programs will help in this coordination.

The Center for Research on Teaching Excellence has provided a great deal of support already to the Applied Mathematical Sciences program assessment. They have helped to organize this initial assessment including holding the student focus group meeting. The applied mathematics faculty value greatly the work that this center does for this program. As the applied mathematics faculty prepare to conduct future assessments, they will look even more to this center for help and support.

The Department of Institutional Planning and Analysis has provided the majority of the data used for this report. Through that work, there have been some initial discussions on how to collaborate to create a dynamic database of student data – a larger scale version of the data collection, analysis and summarizing that Ms. Hedges did earlier. We hope to collect meaningful student performance data each academic year that the applied mathematics faculty will review and use to make decisions for each upcoming academic year. This larger scale effort is crucial for addressing the lower division mathematics courses that affect the entire campus.

The major challenge in addressing the future assessments lies in coordinating all of this data collection and analysis coming from different offices. Ultimately, this work is the responsibility of the applied mathematics faculty. To that end, the applied mathematics faculty have reorganized themselves to address these and other matters. Although the applied mathematics faculty value this assessment work, it does come at the very real and substantial cost of time away from other scholarly duties. While this problem is acknowledged widely across this campus, there exists no real solution. Perhaps as this campus becomes more developed, it can afford to have faculty members spend the time and effort needed for these administrative duties through methods such as teaching relief and acknowledgment of administrative work in academic personnel matters. However, at this early stage of this university, there is no method to free up time to perform these administrative duties. Moreover, there are several more severe time expenditures such as faculty hiring, academic personnel work and many others that conflict with the work needed to manage carefully this program. All of these important matters take time away from the scholarship responsibilities of the faculty. The applied mathematics faculty are concerned deeply that this university has not addressed adequately the faculty workload associated with the administrative needs to build, develop, run and evaluate this new program successfully. Simply stated, this university gives conflicting messages regarding this work. The applied mathematics faculty are striving to strike an appropriate balance between what we perceive as necessary work and scholarly duties even though this university continues to inadequately address this matter. We hope this university will begin to work on this matter immediately.

Data Section for the Self-Review of the Applied Mathematical Sciences Program at University of California, Merced

March 3, 2010

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1 Approved Undergraduate Program Proposal

The file `Mathematics majorrevised4.18.05.pdf` is the program proposal submitted to and reviewed by Undergraduate Council (UGC). After receiving comments from UGC, the revision given by the file `mathmajor.5.23.05.doc` was approved.

2 Program Administration

2.1 Administrative Profile

There are three main programmatic areas of work: (1) lower division service courses, (2) the applied mathematical sciences major and minor, and (3) the applied mathematics graduate group. In addition to this programmatic work, there are other administrative duties requiring attention such as resource allocation, hiring and promotion as well as accreditation which is done by the program lead or chair. The personnel associated with these areas are listed below.

- Program Lead/Chair – Arnold Kim
- Coordinators for the Lower Division Service Courses – Lei, Yue and Arnold Kim
- Coordinators for the Applied Mathematical Sciences Major – François Blanchette (lead), Roummel Marcia and Mayya Tokman
- Coordinators for Graduate Studies in Applied Mathematics – Harish Bhat, Boaz Ilan and Michael Sprague (lead)

2.2 Faculty Membership List

- Harish Bhat, Assistant Professor, School of Natural Sciences
- François Blanchette, Assistant Professor, School of Natural Sciences
- Boaz Ilan, Assistant Professor, School of Natural Sciences
- Arnold Kim, Associate Professor, School of Natural Sciences
- Lei, Yue, Lecturer with Potential for Security of Employment, School of Natural Sciences
- Roummel Marcia, Assistant Professor, School of Natural Sciences
- Michael Sprague, Assistant Professor, School of Natural Sciences
- Mayya Tokman, Assistant Professor, School of Natural Sciences

3 Student Information

3.1 Current Undergraduate Students

See the file `UCM Academic Program Review Data - Math.xlsx`.

3.2 Alumni

There were 7 B.S. degrees in Applied Mathematical Sciences awarded in the 2008-09 academic year. These students are listed below.

- Ms. Alaena Alilin is a graduate student in Applied Mathematics at UC Merced.
- Mr. Jimmy Hiep Nguyen is a DVT Engineer at Juniper Networks in Sunnyvale, CA.
- Ms. Mary Panos is a Level 7 Associate at In-N-Out Burgers in Merced, CA.
- Ms. PeiChen Shu is a R&D Engineer at Landmark Technology in San Jose, CA.
- Mr. William St. Claire is a graduate student in Cognitive Sciences at UC Merced.
- Mr. Paul Tranquilli is a graduate student in Applied Mathematics at UC Merced.
- Ms. Veronica Young is a graduate student in the Department of Biostatistics at George Washington University after a student fellowship in the Research Alliance in Math and Science at Oak Ridge National Laboratory.

The degree data is not available yet for the 2009-10 academic year. That data will not be available until December, 2010. However, there have been 5 applications submitted for Spring 2010 graduation. Those students are listed below.

- Mr. Oren Gazit
- Mr. Karl Lopker
- Ms. Sydney Montroy
- Mr. Luke Poole
- Mr. Bryan Sims

3.3 Benchmark Data

See the files `UCM Academic Program Review Data.xlsx` and `UCM Academic Program Review Data - Math.xlsx` to compare benchmark data for Applied Mathematical Sciences students with students over the entire UC Merced campus.

4 Admitting and Advising Students

4.1 Advising Guidelines

At present, there are no formal advising guidelines for the Applied Mathematical Sciences major beyond the documentation of the degree requirements. To that end, the advising staff have prepared planning sheets for Applied Mathematical Sciences majors with different emphasis tracks. Those planning sheets are given by the files

- `MATH Planning Sheet-Comp. Sci & Engr 21810.pdf`
- `MATH Planning Sheet-Computational Bio 21810.pdf`
- `MATH Planning Sheet-Economics 21810.pdf`
- `MATH Planning Sheet-Engineering Mechanics 21810.pdf`
- `MATH Planning Sheet-Physics Track 21810.pdf`
- `APP MATH Planning Guide-Minor.pdf`

The applied mathematics faculty work closely with the School of Natural Sciences advising staff to clarify policies and procedures for this program. The applied mathematics faculty will consider the development of more formal guidelines in the near future.

4.2 Degree Requirements

The degree requirements are contained in the catalog copy. The most recent catalog copy to be approved by UGC is given in the file `AMS Catalog Copy.doc`.

4.3 Courses Taught

See the file `Math_Enrollments.xls` for a list of all mathematics courses taught along with enrollment figures. The file `Math_Courses Instructors.xls` gives a list of all of the instructors for mathematics courses broken down by semesters.

4.4 Recruitment Materials

The two main recruitment materials for the Applied Mathematical Sciences program are the website: `http://appliedmath.ucmerced.edu` and the brochure (see `AppliedMathBrochure.pdf`). In addition, we have included a sample recruitment letter (see the file `Letter to Applied Math Students.doc`) and a sample email (see the file `Recruitment Email.txt`) that we have used to recruit potential students into this program.

5 Faculty Information

5.1 Harish Bhat

- Ph.D. in Control and Dynamical Systems, California Institute of Technology, 2005.
- My areas of expertise are: (1) analysis and simulation of electrical circuits using ideas from linear and nonlinear waves, perturbation theory, and numerical analysis; (2) analysis of models for gas dynamics and compressible fluid flow using methods of geometric mechanics and Hamiltonian partial differential equations.
- For 2008-09 academic year, served on the faculty search committee and the graduate admissions committee. For 2009-10 academic year, served on the graduate program committee.
- 13 peer-reviewed journal publications, 3 peer-reviewed conference publications, 5 manuscripts submitted and under review. The 5 key publications:
  1. H. S. Bhat and B. Osting [2009], Diffraction on the two-dimensional square lattice, *SIAM Journal on Applied Mathematics*, **70**, 1389–1406.
  2. H. S. Bhat and R. C. Fetecau [2009], The Riemann problem for the Leray-Burgers equation, *Journal of Differential Equations*, **246** (10), 3957–3979.
  3. E. Afshari, H. S. Bhat, and A. Hajimiri [2008], Ultrafast analog Fourier transform using two-dimensional LC lattice, *IEEE Transactions on Circuits and Systems I*, **55** (8), pp. 2332–2343.
  4. H. S. Bhat and E. Afshari [2008], Nonlinear constructive interference in electrical lattices, *Physical Review E*, **77**, 066602.
  5. H. S. Bhat and R. C. Fetecau [2006], A Hamiltonian regularization of the Burgers equation, *Journal of Nonlinear Science*, **16** (6), 615–638.
- Professional awards and honors (three lines maximum):
  1. 2007: awarded three-year $95,452 grant from the National Science Foundation to develop numerical methods and optimization algorithms for the design of high-speed analog circuits.
  2. 2005: first place at the Stanford-Berkeley-Caltech Innovators Challenge, in collaboration with E. Afshari and A. Hajimiri.
  3. 2000: awarded three-year National Science Foundation Graduate Research Fellowship in the Mathematical Sciences.
- Five most recent conferences:
  1. 2009 SIAM Conference on Mathematics in Industry, San Francisco, CA.
  2. 2008 IEEE Asia-Pacific Microwaves Conference, Hong Kong, China.
  3. 2008 International Symposium on Antennas and Propagation, Taipei, Taiwan.
  4. 2008 Fall Western Section Meeting of the American Mathematical Society, Vancouver, Canada.
  5. 2008 Spring Western Section Meeting of the American Mathematical Society, Claremont, CA.
- Service to the profession: refereed papers for *Proceedings of the Royal Society: Series A*, *Journal of Nonlinear Science*, *Physica D*, and *Journal of Physics A*. Evaluated a grant proposal for MITACS (see http://www.mitacs.math.ca/index.htm).

5.2 François Blanchette

- Ph.D. Massachusetts Institute of Technology, 2003
- Area of expertise – Fluid dynamics, with an emphasis on suspensions (particle and heat-transport, instabilities) and free-surface flows (coalescence, drop dynamics, mixing within drops).
- Committee Membership – Lead of the Applied Mathematics major, Member of search committees for lecturers and faculty members. Membership in the program's commmittees and other services to the program or university
- Dr. Blanchette has 13 peer-reviewed publications, 1 patent, 1 proceedings, 2 poster presentations. Five key works include the following.
  1. "Partial coalescence of drops at liquid interfaces," Blanchette, F., Bigioni, T.P., *Nature Physics*, Vol. 2 (4), pp. 254–257, 2006.
  2. "High-resolution numerical simulations of resuspending gravity currents: Conditions for self-sustainment," Blanchette, F., Strauss, M., Meiburg, E., Kneller, B., Glinsky, M.E., *Journal of Geophysical Research-Oceans*, Vol. 110 (C12), C12022, 2005.
  3. "Flow lines and mixing within drops in microcapillaries," Blanchette, F., *Physical Review E*, Vol. 80 (6), 2009.
  4. "Dynamics of drop coalescence at fluid interfaces," Blanchette, F., Bigioni, T.P., *Journal of Fluid Mechanics*, Vol. 620, pp. 333–352, 2009
  5. "Particle concentration evolution and sedimentation-induced instabilities in a stably stratified environment," Blanchette, F., Bush, J.W.M., *Physics of fluids*, Vol. 17 (7), 073302, 2005
- Professional awards and honors
  - NSF (DMS) grant: "Simulations of Surface Tension Driven Flows and Interactions Between Fluid Flow and Solid Particles," 2008-2011.
- Conference participation and lectures
  - Meeting presentations: APS-DFD meeting (2001, 2003-09), SoCAMS (2004), Dynamics Days (2006).
  - Seminars given at: MIT (2000-03, 2005), UCSB (2003, 05), U. Chicago (2005-06), Beijing University (2005), Stanford (2006), U. of Alberta (2006), U. of Waterloo (2006), York U. (2006), UC Merced (2006-09), UC Berkeley (2006), UC Davis (2007), CSU Bakersfield (2008), CSU Fresno (2008).
- Service to the profession
  - Reviewer for: Petroleum Research Fund (grant), NSERC Engineering and Natural Sciences (grant), Physical Review Letters, Journal of Fluid Mechanics, European Journal of Mechanics -B/Fluids, Physical Review E, Physics of Fluids.
  - Presentation Chair for APS-DFD meeting (2005-2006).

5.3 Boaz Ilan

- Ph.D., Tel Aviv University, 2002
- Area of expertise – the interface between mathematics and real-world phenomena. Dr. Ilan uses differential equations and numerical computations to model problems in laser propagation and solar science.
- Since 2005 Dr. Ilan has served on various UC Merced committees, including:
  - Applied Math Search Committees (2005–2009)
  - Applied Math Graduate Committee (2009)
  - School of Natural Sciences Academic Resources and Planning Committee (2005-2009).

  Dr. Ilan participated in several outreach events, including Bobcat Day and Dinner With A Scientist.
- To date Dr. Ilan has 28 publications in peer-reviewed journals. Five significant journal articles:
  1. M. A. Hoefer and B. Ilan, Theory of two-dimensional oblique dispersive shock waves in supersonic flow of a superfluid, Physical Review A, Rapid Communications, 2009.
  2. K. A. Mitchell and B. Ilan, Nonlinear enhancement of the fractal structure in the escape dynamics of Bose-Einstein condensates, Physical Review A, 2009.
  3. Q. Quraishi, S.T. Cundiff, B. Ilan, and M.J. Ablowitz, Dynamics of nonlinear and dispersion managed solitons, Physical Review Letters, 2005.
  4. . G. Fibich, B. Ilan, and G.C. Papanicolaou, Self-focusing with fourth-order dispersion, SIAM Journal on Applied Mathematics, 2002.
  5. G. Fibich and B. Ilan, Vectorial and random effects in self-focusing and in multiple filamentation, Physica D, 2001.
- Professional awards and honors:
  - NSF SOLAR Grant ”Luminescent Solar Concentrators Based on Semiconductor Nanorods”, 2009–2012 (co-PI).
  - NSF MRI Grant 2008-2011 (co-PI).
  - George S. Wise Award for Excellence in Ph.D. Studies, Israel, 2002.
- Conference participation and lectures – More than 30 presentations at scientific meetings and departmental seminars and colloquia. Recent invited presentations:
  - Department of Mathematics, University of Illinois at Urbana-Champaign (Oct. 2009).
  - Workshop on Analysis of nonlinear wave equations and applications in engineering, Banff, Canada (Aug. 2009).
- Professional awards and honors
  - Organized two mini-symposia at international meetings (2004 & 2008)
  - Organizing a mini-symposium planned for June 2010 (Beijing, China).
  - Peer-reviewer for more than 12 journals in mathematics, physics and engineering disciplines. Member of SIAM and OSA.

5.4 Arnold D. Kim

- Ph.D. in Applied Mathematics from University of Washington in 2000
- Area of expertise – wave propagation in random media, numerical analysis and scientific computing, asymptotic analysis and inverse problems applied to biophotonics.
- Committee Membership – A summary of Dr. Kim's committee membership is given below.
  - Applied Mathematical Sciences Program – Serves as program lead for the Applied Mathematical Sciences program with duties similar to a department chair. Faculty accreditation officer for the Applied Mathematical Sciences major and minor.
  - School of Natural Sciences – Has served as Faculty Chair for the 2006-2007 and 2007-2008 academic years. Has served as Faculty Vice-Chair for the 2008-2009 academic year. Has been serving as an Academic Personnel Committee co-chair since the 2007-2008 academic year. Currently serving as the School Committee-on-Committees chair.
  - Univeristy Committees – Has served as the Divisional Council Member-At-Large for the 2005-2006 and 2006-2007 academic years. Has been serving on the Committee-on-Committees since the 2007-2008 academic year. Member of the School of Management steering committee. Member of the WASC Steering Committee.
- Dr. Kim has over 30 peer-reviewed publications. Five key works include the following.
  1. P. González-Rodríguez and A. D. Kim, "Comparison of light scattering models for diffuse optical tomography," *Optics Express* **17**, 8756-8774 (2009) [Also cited in *The Virtual Journal for Biomedical Optics* **2**: 7 (2009)].
  2. J. Clark, P. González-Rodríguez and A. D. Kim, "Using polarization to find a source in a turbid medium," *Journal of the Optical Society of America A* **26**, 1129-1138 (2009) [Also cited in *The Virtual Journal for Biomedical Optics* **2**: 7 (2009)].
  3. P. González-Rodríguez and A. D. Kim, "Reflectance optical tomography in epithelial tissues," *Inverse Problems* **25**, 015001 (2009).
  4. P. González-Rodríguez and A. D. Kim, "Light propagation in two layer tissues with an irregular interface," *Journal of the Optical Society of America A* **25**, 64-73 (2007) [Also cited in *The Virtual Journal of Biological Physics Research* **15**: 3 (2008)].
  5. A. D. Kim and P. Tranquilli, "Numerical solution of the Fokker-Planck equation with variable coefficients," *Journal of Quantitative Spectroscopy and Radiative Transfer* **109**, 727-740 (2007).
- Professional awards and honors
  - National Science Foundation Mathematical Sciences Postdoctoral Fellowship Department of Mathematics, Stanford University (August 2000 - July 2003).
  - Departmental Award for Teaching and Service Department of Applied Mathematics, University of Washington (November 1999).
- Conference participation and lectures – Dr. Kim participates actively in several conferences and professional meetings. For example, he has given twenty-two invited talks since his arrival to UC Merced.

- Service to the profession – Dr. Kim reviews several manuscripts each year for publication in scientific and mathematics journals. He has served on panels to review grant proposals for the National Science Foundation and the Department of Energy. He is a member of the Society of Industrial and Applied Mathematics and the Optical Society of America.

5.5 Lei, Yue

- Ph.D. in Mathematics from Massachusetts Institute of Technology, 2001
- Area of expertise – low-dimensional topology and geometry
- Committee Membership – coordinator of lower-division math courses
- Key publications are listed below

  1. "Energy considerations for multiphase fluids with variable density and surface tension," with François Blanchette *SIAM Review*, Volume 51, Issue 2, pages 423-431.
  2. "The regularity of the eta function for perturbations of order -(dim X) of the Atiyah-Patodi-Singer boundary problem," *Communications in Partial Differential Equations*, Volume 28, No. 9-10, 2003.
  3. "The eta invariant for manifolds with boundary and holomorphic maps into the restricted Grassmannian," *Ph.D. thesis*, Massachusetts Institute of Technology, February, 2001.

5.6 Roummel Marcia

- Highest degree: Ph.D., University of California, San Diego, 2002
- Area of expertise: Computational mathematics, large-scale optimization, numerical linear algebra, image processing, computational biology
- Services to the program: Applied math faculty search committee, organizer of the applied math seminar
- Number of publications: 13 journal papers (10 published, 1 accepted, and 2 submitted), 11 conference proceedings (7 published, 2 accepted, and 2 submitted), 1 book chapter (in revision).

  Five key publications or works:

  – R. F. MARCIA. On solving sparse symmetric linear systems whose definiteness is unknown, *Appl. Num. Math.*, 58:4, pp. 449–458, (2008).
  – R. E. BANK, P. E. GILL, AND R. F. MARCIA. Interior Methods for a Class of Elliptic Variational Inequalities, in L. T. Biegler, O. Ghattas, M. Heinkenschloss and B. Waanders (eds) *Large-scale PDE-constrained Optimization*, Lecture Notes in Computational Science and Engineering, Volume 30, 218–235, Springer Verlag, Berlin, Heidelberg and New York (2003).
  – R. F. MARCIA AND J. BEN ROSEN. Convex quadratic approximation, *Comp. Opt. Appl.* **28**, 173–187, (2004)

- J. R. BUNCH AND R. F. MARCIA. A pivoting strategy for symmetric tridiagonal matrices, *Num. Lin. Alg. Appl* **12**, 911–922, (2005).
- R. F. MARCIA, J. C. MITCHELL, AND S. J. WRIGHT. Global optimization in protein docking using clustering, underestimation, and semidefinite programming, *Opt. Meth. Soft.* **22**:5, 803–811 (2007).

- Awards: Computational and Informatics in Biology and Medicine Fellowship (2004-2006), UC San Diego Fellowship (1995-1997).
- Grants: National Science Foundation (DMS-0811062): Second-order methods for large-scale optimization in compressed sensing, Principal Investigator.
- Conference participation and lectures: over 25 conference presentations.
- Service to the profession: National Science Foundation grant review panelist, Society for Industrial and Applied Mathematics Professional Development organizer

5.7 Michael Sprague

- Ph.D. in Mechanical Engineering from University of Colorado at Boulder in 2002.
- Areas of expertise – Computational mechanics of structures, fluids, and their interaction, computational boundaries for unbounded domains, and scientific computing.
- Committee Membership – A summary of Dr. Sprague's committee membership is given below.
  - Applied Mathematics Program – Serves as the faculty lead for graduate studies in applied mathematics (2005 - present).
  - School of Natural Sciences – Served as a member of the Curriculum Committee (2005-2006), Dean's Faculty Advisor Group for Development (2005-2006), Member-at-Large of the Executive Committee (2006-2007), Chair of Committee on Committees (2007-2009).
  - University Committees – Served as a memeber of the Strategic Academic Planning Committee (2007-2008).
- Number of publications, performances and exhibits and five key publications or works – Dr. Sprague has published 16 papers in peer-reviewed journals; five significant publications are listed below
  1. T.L. Geers and M.A. Sprague, 2010, "A residual-potential boundary for time-dependent, infinite-domain problems in computational acoustics," to appear in *Journal of the Acoustical Society of America*.
  2. M.A. Sprague and P.D. Weidman, 2009, "Continuously tailored Taylor vortices," *Physics of Fluids*, **21**, 114106.
  3. M.A. Sprague and T.L. Geers, 2008, "Legendre spectral finite elements for structural dynamics analysis," *Communications in Numerical Methods in Engineering* **24**, 1953–1965, DOI: 1002/cnm.1086.

4. M.A. Sprague, K. Julien, E. Knobloch, and J. Werne, 2006, "Numerical simulation of an asymptotically reduced system for rotationally constrained convection," *Journal of Fluid Mechanics* **551**, 141–174.
5. M.A. Sprague and T.L. Geers, 2004, "A spectral-element method for modeling cavitation in transient fluid-structure interaction," *International Journal for Numerical Methods in Engineering* **60**, 2467–2499.

- Professional awards and honors – NSF VIGRE Postdoctoral Scholar (2003-2005)
- Conference participation and lectures – Dr. Sprague has contributed presentations at 13 conferences, including the American Physical Society Fluid Dynamics meetings, the SIAM Conference on Mathematical & Computational Issues in the Geosicences, and the United States National Congress on Theoretical and Applied Mechanics.
- Service to the profession (including consulting, where appropriate) – Dr. Sprague is a member of American Physical Society, American Society of Mechanical Engineers, and Society for Industrial and Applied Mathematics. He has served as a Peer reviewer for 16 different journals.

5.8 Mayya Tokman

- Ph.D. in Applied Mathematics from California Institute of Technology in 2001.
- Area of expertise – Numerical analysis, scientific computing
- Committee membership – A summary of Dr. Tokman's committee membership is given below.
  - Faculty director for the Science and Mathematics Initiative (SMI)
  - Served as a member of curriculum committee for the School of Natural Sciences
  - Served as a member of the hiring committees both for the Applied Math program searches and for the Vice Provost for Student Affairs position.
- Publications
  - *Efficient Integration of Large Stiff Systems of ODEs with Exponential Propagation Iterative (EPI) Methods*, M. Tokman, Journal of Computational Physics 213 (2006) 748776.
  - *Three-dimensional Model of the Structure and Evolution of the Coronal Mass Ejections*, M. Tokman, P. Bellan, Astrophysical Journal, 567(2), (2002) 1202.
  - *Investigations into the Relationship between Spheromak, Solar and Astrophysical Plasmas*, P.M. Bellan, S.C. Hsu, J.F. Hansen, M. Tokman, S.E. Pracko, C.A. Romero-Talamas, Proceedings on 19th International Atomic Energy Agency Fusion Energy Conference, Lyon, 2002.
- Professional awards and honors
  - 2005-2006 AAAS Policy Fellowship
  - 2002 Marshall N. Rosenbluth Outstanding Doctoral Thesis Award, APS.
  - 2001 W. Carey Prize for Outstanding Thesis in Applied Mathematics, Caltech.

- Conference participation and lectures
  - NCAR Frontiers in Geophysical Simulation Workshop, Boulder, CO (August 2009).
  - Extreme Scale Computing in Fusion Research DOE Workshop, Washington, DC (March 2009).
  - SIAM Computational Science & Engineering Conference, Miami, FL (March 2009).
  - Applied Mathematics Seminar, Department of Mathematical Sciences, University of Delaware (November 2008).
  - Numerical Methods Seminar, Princeton Plasma Physics Laboratory, Princeton, NJ (November 2008).
  - Applied Mathematics Colloquium, Applied Physics and Applied Mathematics Department, Columbia University (Novermber 2008).
  - International Young Investigator Symposium, Oak Ridge, TN (October 2008).
  - Computational Methods in Transport Workshop, Tahoe, CA (September 2008).
  - GLADE Numerical Methods for ODEs Conference, Auckland, New Zealand (July 2008).
  - US-France Young Scientists Meeting, Washington, DC (October 2007).
  - Joint Meeting of American and New Zealand Mathematical Societies, Wellington, New Zealand (December 2007).
  - Nano-Bio Workshop, Urbana-Champaign, Illinois (August, 2007).
  - SCICADE International Conference on SCIentific Computation And Differential Equations, Saint-Malo, France (July 2007).
  - Applied Mathematics Seminar, Mathematics Department, University of California, Irvine (April 2007).
  - Numerical Solution of Differential and Differential-Algebraic Equations Workshop, Halle (Saale), Germany (September, 2006).
  - Mathematics Colloquium, Mathematics Department, University of California, Berkeley, CA (October 2004).
  - High Altitude Observatory Colloquium, NCAR, Boulder, CO (October 2004).
  - Space Sciences Laboratory Seminar, Berkeley, CA (April 2003).
  - Division of Plasma Physics Meeting, American Physical Society (APS), Orlando, FL (November 2002).
  - High Altitude Observatory Colloquium, NCAR, Boulder, CO (May 2002).
  - Mathematics Colloquium, Mathematics Department, University of California, Berkeley (October 2001).
  - Applied Physics Seminar, Caltech, Pasadena (November 2000).
  - Jet Propulsion Laboratory Seminar, Pasadena (November 2000).
  - U.S. Naval Research Laboratory Seminar, Washington, D.C. (November 2000).
  - Informal Applied Mathematics Seminar, Caltech, Pasadena (November 2000).
- Service to the profession
  - Served on the selection and steering committees for the Department of Energy Computational Science Graduate Fellowship (CSGF) program, organized networking for alumni and fellows of the CSGF program

- Served as a reviewer for SIAM Journal of Scientific Computing and Journal of Computational Physics.

6 Learning Outcomes Assessment

See the file `AMS PLO Assessment.pdf`. In addition, please refer to the following files that the applied mathematics faculty have been using to perform informal assessments.

1. `Fall 2007 Lower Division Math Course Summary.pdf`
2. `Spring 2008 Lower Division Math Course Summary.pdf`
3. `Fall 2008 Lower Division Math Course Summary.pdf`
4. `Spring 2009 Mid-Semester Lower Division Math Course Summary.pdf`
5. `Spring 2009 Lower Division Math Course Summary.pdf`
6. `Fall 2009 Lower Division Math Course Summary.pdf`

Program Learning Outcomes Assessment

Applied Mathematical Sciences Program
University of California, Merced

January 30, 2010

Abstract

The applied mathematics faculty performed an initial assessment of the Applied Mathematical Sciences program. In particular, we studied two program learning outcomes: (1) solve mathematical problems analytically and (2) solve mathematical problems using computational methods using direct (embedded questions) and indirect (student focus group discussion) evidence. Through this initial assessment, the applied mathematics faculty discovered that they need to work together in the near future to develop a more coherent set of standards for assessing student progress with respect to these program learning outcomes. Consequently, the applied mathematics faculty has made concrete proposals for next steps for future assessments. Moreover, the applied mathematics faculty gives some insight on the resource implications of doing these future assessments.

1 Introduction

The Applied Mathematical Sciences program at UC Merced provides students with knowledge of the foundations of mathematics and the skills needed to apply mathematics to real-world phenomena in the social sciences, natural sciences and engineering. The over-arching goal of the Applied Mathematical Sciences program is to

> ***Build a community of life-long learners that use the analytical and computational tools of mathematics to solve real-world problems.***

More specifically, the program learning outcomes of the Applied Mathematical Sciences program are as follows.

> Upon graduating, we expect students completing the Applied Mathematical Sciences major to have become effective *problem-solvers*, meaning that student will be able to
>
> 1. Solve mathematical problems using analytical methods.
> 2. Solve mathematical problems using computational methods.
> 3. Recognize the relationships between different areas of mathematics and the connections between mathematics and other disciplines.
> 4. Give clear and organized written and verbal explanations of mathematical ideas to a variety of audiences.
> 5. Model real-world problems mathematically and analyze those models using their mastery of the core concepts.

The original plan was to assess initially only the first program learning outcome. However, after a meeting with Arnold D. Kim, Michael Roona and Anne Zanzucchi on Wednesday, August 26 (see Section 7.1 for a summary of that meeting and Section 7.2 for a summary of a follow up meeting) to discuss this plan, the applied mathematics faculty decided to do an initial assessment of the first two program learning outcomes listed above. In particular, the faculty decided to focus this initial assessment effort on two critical "transition" courses: Math 121 and Math 131. Math 121 is the first upper division course for the major in which students study intermediate and advanced analytical methods for solving ordinary and partial differential equations. Math 131 is the first upper division course for the major in which students learn numerical analysis.

The applied mathematics faculty has made this change of plan because these two courses are critical for the program's consideration. By performing this assessment, the faculty hopes to see how well their students entering into the major are prepared for upper division courses. In addition, the faculty hopes to obtain an indication of what can reasonably be expected for subsequent upper division courses. Thus, the faculty will become more informed as they take on the task of assessing our lower division courses. In addition, the faculty hopes to obtain an indication of what can be expected reasonably for the subsequent upper division courses. In doing so, the faculty hopes to obtain a better understanding of Applied Mathematical Sciences students that will translate directly to developing new courses, namely a capstone modeling course. In other words, the applied mathematics faculty is using this initial assessment to initiate a *cascade downward* to assess lower division service courses and a *cascade upward* to assess the major.

2 Assessment methods

The procedure for assessing achievement of the first and second program learning outcomes utilized both a direct (embedded questions) and an indirect (focus group discussions) method.

2.1. Embedded Homework and Final Exam Questions

The following questions were embedded in the Math 121 and Math 131 courses. For Math 121, the faculty is assessing PLO 1 and for Math 131, the faculty is assessing PLO 2. Each of the solutions for the embedded questions was assessed using the rubric agreed upon by the applied mathematics faculty (see Sections 7.4 and 7.5 for the initial rubrics used in this assessment exercise). Each faculty member performed this initial assessment individually. After this initial assessment exercise, the applied mathematics faculty met as a group to discuss the collective results. In addition, the applied mathematics faculty discussed the re-evaluation and revision of their original rubric based on this initial assessment experience.

The applied mathematics faculty chose two problems to embed in the Math 121 course to provide an assessment of PLO 1. The Math 121 embedded homework question is given by the following.

> Consider the heat equation
> $$\frac{\partial u}{\partial t} = c\frac{\partial^2 u}{\partial x^2}$$
> on the interval $[0, L]$ with mixed boundary conditions $u(0,t) = 0$ and $\frac{\partial u}{\partial x}(L,t) = 0$. Suppose we tell you that the initial condition is
> $$u(x,0) = h(x),$$
> where $h(x)$ is a smooth function of x that satisfies the boundary conditions $h(0) = 0$ and $h'(L) = 0$. Describe the full solution $u(x,t)$ of the heat equation, using the tools of separation of variables and a Fourier-type expansion in an appropriate set of eigenfunctions.

The Math 121 embedded final exam question is given by the following.

> Consider the ordinary differential equation
> $$u'' - 2xu' + 2pu = 0,$$
> where p is a positive integer and $u(x)$ is an unknown function of x.
>
> 1. Use power series to construct the solution $u(x)$. You should find a recurrence relation, but you do *not* need to solve the recurrence relation in closed form.
> 2. Show that it is always possible to choose the first two constants in the power series solution in such a way that the series terminates and the overall solution is a polynomial.

The applied mathematics faculty chose two problems to embed in the Math 131 course to provide an assessment of PLO 2. The Math 131 embedded homework question is given by the following.

[In previous problems, students were asked first to implement the second order and fouth order Runge-Kutta schemes] Use the two programs you wrote to solve

$$\frac{dx}{dt} = -x, \quad x(0) = 5.$$

1. Calculate $x(1)$ and $x(8)$ using $h = 0.001$, 0.01, 0.1, 1, 2 and 4.
2. Find the rate of convergence (big "oh") of the absolute error of your solution as $h \to 0$.

The Math 131 embedded final exam question is given by the following.

Find the order of the following differentiation formula using any method you like.

$$f'(x_0) \approx \frac{-(3/2)f(x_0) + 2f(x_0 + h) - (1/2)f(x_0 + 2h)}{h}$$

Using **another** differentiation formula that you know to be of order 3, you found using $h = 0.2$, $D_{0.2} = 4.25$, and using $h = 0.1$, $D_{0.1} = 4.11$. Estimate the error made when using $h = 0.1$.

2.2. Student Focus Group Questions and Activities

With the assistance of Anne Zanzucchi and Adriana Signorini from the Center for Research and Teaching Excellence, the applied mathematics faculty conducted a focus group discussion with several students that took both Math 121 and Math 131 in Fall Semester 2008. The purpose of this student focus group was to hold a conversational and informal discussion about the major with the purpose of identifying the following items.

- Key aspects of your learning experience,
- What has been of most value to you and why,
- What has been challenging for you and why, and
- Strategies for improving the program.

Below is a description of the Focus Group Questions and Activities. The applied mathematics faculty credits Anne Zanzucchi for developing this plan and Adriana Signorini for coordinating the actual group meeting.

Goal: The focus of this session is to determine key responses to students' learning experiences in the major program. The interview concludes with a problem-solving opportunity to ensure constructive and applicable feedback.

Topics of Interest: Program Learning Outcomes

Brainstorming (15 minutes)

(1) Take about 2-3 minutes to list or write a brief paragraph about your primary experiences as an Applied Mathematics student. What are the immediate images, concepts, or phrases that come to mind?
(2) Exchange your writing with a partner, take about 5 minutes to read and discuss responses. It is not necessary to agree on a unified perspective, though to identify what appear to be a few positive and a few negative responses worth sharing with the group
(3) Pairs report to the group about main ideas; focus group leader will list on board

Program Learning Outcomes

(4) Share paper copy of PLOs 1 & 2, how are we doing?
(5) Given these PLOs, how applicable has MATH 131 / 121 been to the next step in your Applied Mathematics major?

Elaboration (15 minutes)

(6) At what point (or which project) did you really feel as though you were fully engaged with Applied Mathematics?
(7) Have there been teaching practices that have been particularly effective at supporting your learning? How so?

Conclusion (5 minutes): Summary of general student consensus. What are the key points that the faculty should know?

3 Results

3.1 Assessment Results for Embedded Questions

Using the rubrics given in Sections 7.4 and 7.5, the applied mathematics faculty assessed the student work in the embedded homework and exam problems. For each student solution, each faculty member gave a rating of *poor*, *fair* or *good*. Next, the faculty assigned numerical values of -1, 0 and +1 to ratings for *poor*, *fair* and *good*, respectively. Using those numerical values, the faculty organized the results as an Assessment Matrix. The rows of this matrix correspond to a particular student and the columns of this matrix correspond to a particular applied mathematics faculty member. There is one Assessment Matrix for each of the embedded homework and exam problems. The applied mathematics faculty used this numerical coding of the results because it allows for more detailed statistical analysis.

Tables 1 – 4 give the Assessment Matrices for each of the embedded homework and exam problems for PLO's 1 and 2.

If one reads across any row of these Assessment Matrices given above, one finds that there is no unanimous agreement about student performance. A more detailed statistical analysis (not shown here) confirms that the applied mathematics faculty had a diversity of opinions regarding student performance.

Table 1. Assessment Matrix for the embedded homework problem used to assess PLO 1.

	Bhat	Blanchette	Ilan	Kim	Lei	Marcia	Sprague	Tokman
A	0	0	0	-1	1	0	0	-1
B	1	1	0	0	0	0	0	1
C	-1	1	1	0	0	0	0	1
D	-1	1	1	0	0	0	0	1
E	1	1	0	1	1	0	0	1
F	1	1	-1	0	1	0	0	-1
G	0	0	-1	0	0	1	0	0

Table 2. Assessment Matrix for the embedded exam problem used to assess PLO 1.

	Bhat	Blanchette	Ilan	Kim	Lei	Marcia	Sprague	Tokman
A	0	0	1	-1	0	0	0	0
B	0	0	-1	0	-1	-1	-1	0
C	-1	-1	-1	-1	-1	-1	0	-1
D	-1	-1	-1	-1	-1	-1	-1	-1
E	0	-1	1	-1	-1	0	-1	0
F	0	0	1	-1	0	0	0	0
G	0	0	1	-1	0	0	0	0
H	0	0	-1	-1	0	-1	0	0
I	0	-1	0	-1	-1	0	-1	-1

Table 3. Assessment Matrix for the embedded homework problem used to assess PLO 2.

	Bhat	Blanchette	Ilan	Kim	Lei	Marcia	Sprague	Tokman
A	-1	0	0	0	1	1	0	-1
B	0	1	1	0	0	1	1	0
C	-1	1	1	0	0	0	1	1
D	1	0	0	1	1	0	1	0
E	-1	0	-1	-1	-1	-1	0	-1
F	-1	0	-1	-1	-1	-1	-1	-1
G	0	1	0	0	0	1	0	-1

Table 4. Assessment Matrix for the embedded exam problem used to assess PLO 2.

	Bhat	Blanchette	Ilan	Kim	Lei	Marcia	Sprague	Tokman
A	0	0	-1	0	0	-1	-1	-1
B	0	0	-1	-1	-1	-1	-1	-1
C	0	1	1	0	1	0	0	0
D	1	0	0	0	0	0	0	0
E	0	0	0	0	0	-1	0	1
F	0	-1	0	0	0	-1	-1	0
G	-1	0	-1	-1	0	1	-1	-1
H	1	1	1	0	1	1	1	1

In the group discussion of these results, the applied mathematics faculty discovered why there were such widely varying assessment results. The diversity of results lies in each faculty member's application of the rubrics to the student solutions. Some attempted to apply the rubrics with a strict interpretation to the student work. Others made adjustments as they evaluated student work. Those that made adjustments to their interpretation of the rubric did so because they felt that the rubrics were calling for items that extended too far for students at this level of their education. In particular, the items that mention "making adjustments to strategy" were too difficult to assess from this work. Overall, the applied mathematics faculty felt that the rubrics do not apply too well to the broad variety of problems that they have studied and hope to study in the future. Moreover, the faculty agreed that using only three tiers for assessment (i.e. good, fair and poor) is too coarse.

3.3 Results from Student Focus Group Discussion

Adriana Signorini coordinated the Student Focus Group Discussion held on Tuesday, January 19, 2010. Her written summary of this meeting appears in Section 7.6. The applied mathematics faculty would like to take this opportunity to thank her sincerely for this work.

The applied mathematics faculty was pleased overall with the results of the Student Focus Group Discussion. The faculty interpreted the student statements about their learning experiences to be largely positive. Moreover, the faculty gained a lot of valuable insight from the student remarks that they plan to use to improve the curriculum.

In particular, the faculty was pleased to hear that students wanted more early programming experience. The faculty agrees that students should develop sophisticated programming skills and that their early computer programming learning experiences are critical for their success in this regard. In fact, the applied mathematics faculty have been considering already developing a lower division course to help students develop their programming skills and gain sophistication in their ability to implement, test and validate algorithms. Moreover, we are trying to incorporate these skills more explicitly throughout the curriculum. For example, Professor Bhat used Matlab/Octave programming language in his Math 32 course in Fall Semester of 2009 to give students extra exposure to mathematical programming. Professor Lei is continuing the use of computer programming in Math 32 this current semester, but using the R statistical programming language. Now that the faculty is aware of students wanting this kind of a course, the faculty has planned to make its development a priority in the near future.

The applied mathematics faculty was surprised to learn that some students wanted a writing class that aligned more closely to the writing done in mathematics. The applied mathematics faculty have discussed at length in several meetings topics related to PLO 5. In particular, the applied mathematics faculty wishes to address a need to help students understand expectations in communicating mathematics correctly. For example, if a problem asks a student to "show" a particular mathematical statement (as in part 2 of the embedded exam problem for PLO 1), the student must use their knowledge of the problem to have that mathematical statement emerge naturally from a sequence of logically correct arguments. These mathematical communication skills take time to develop, especially as a student's mathematical knowledge and skills are developing. The applied mathematics faculty does not feel that an entire mathematical writing course is the best near-term solution. However, the applied mathematics faculty initiated a discussion on how to have students continually develop their mathematics communications skills as they progress through the curriculum. By the time the faculty

assesses PLO 5, the applied mathematics faculty hopes to have some specific items in place throughout the entire curriculum that are meant to help students develop these communication skills.

4 Conclusions and recommendations

4.1 Student Learning

Overall, the applied mathematics faculty was pleased with the student work in the embedded questions and the feedback that students gave in the student focus group discussion. There was unanimous consensus that both the direct and indirect methods gave valuable insight into the progress of this program. To that end, the applied mathematics faculty plan to continue using these methods as they continue to assess the Applied Mathematical Sciences PLO's.

One significant issue is the lack of evidence available at present to evaluate and assess the program. While the evidence collected thus far is valuable for these initial assessments, the data are not sufficiently rich that the applied mathematics faculty can determine useful statistical information. In other words, the applied mathematics faculty feels that the best mode of analysis is looking carefully at individual cases. The applied mathematics faculty seeks to extract as much useful information from the data, but at the same time, they are careful to not draw too many conclusions from this data. Indeed, the applied mathematics faculty agrees that it is better to investigate something in depth rather to make a superficial study of a larger area. At this time, the faculty does not see this situation as a disadvantage. Rather, the faculty feels that this detailed approach contributes directly to the sentiments from students that they appreciate that "faculty were always available to help."

From what the applied mathematics faculty has learned from this assessment, the faculty has agreed to pursue the following steps to help improve student learning with respect to the PLO's.

1. Consider developing a lower-division programming class to provide students a meaningful early experience in developing their programming skills which will enable them to succeed better at achieving PLO 2.

2. Develop a continuous "thread" throughout the curriculum to help develop student's skills in communicating mathematics, correctly and effectively.

3. Work together more often to build a coherent consensus on assessment and evaluation student learning.

Prior to undertaking these particular assessments, the applied mathematics faculty has made several revisions to the curriculum. All of these revisions have come from learning about student success in our classes, albeit less formally than is described in this report. Some of these curriculum changes are under review currently. A description of these changes appears below.

4.1.A Restructuring Pre-calculus

In Fall 2005, the campus' inaugural semester, roughly 140 students placed into Calculus I or II, versus approximately 400 who placed into pre-calculus. The pre-calculus course, Math 5, initially followed the model of most large universities: students met in a large lecture (200 students/class) several times a week, and also met in small discussion sections (25 students each) with a TA. The faculty adopted the

Treisman workshop-style discussion sections, so students spent a majority of their time working on problems in section, rather than watching the TA solve problems. They chose as a text the #1-seller for this course that several other UC campuses use.

Early in the semester, however, the faculty began to detect real difficulties: student performance on the first midterm exam was dismal overall; the *esprit de corps* of the class was poor within just a few weeks; and students and teachers alike seemed frustrated by the course, but were unable to figure out how to make dramatic improvements. Among other challenges, everyone in the course felt that there was a lack of coherence: the text leapt from one topic to another, initially moving, for example, from absolute values one day to solving equations the next, to rectangular coordinates the next, and so on. Students felt like they weren't making progress in building deep understanding of any particular topic, and felt instead like they were simply revisiting material they had seen in earlier math classes, only at a much faster pace. As one colleague stated: "How can they be motivated when the reward they perceive for surviving this class is more of the same in future semesters?" (In fact that's not true, since the calculus courses are much better in many ways, but these students had no way of knowing that.)

While the faculty predicted a high failure rate for students' final grades, they were unprepared for the ultimate statistic: over 50% of the students did not pass the class. (This number does not account for students who dropped the course sometime during the semester.) Worse, the faculty all had concerns about students who passed with a low-C: while they may have "passed," the faculty did not feel that they were well prepared for future courses. This was deemed by all as a simply unacceptable outcome.

During the middle of the semester, the faculty began to search for a different model of teaching this class, looking for best practices at other large universities. The faculty identified an outstanding one at the University of Michigan, which has a long track record of helping large numbers of students excel through their introductory courses. After corresponding and visiting with the University of Michigan faculty in charge of the program, the applied mathematics faculty decided to implement Michigan's model for the Spring semester. This adoption represents a huge shift for this large course in which they faculty has responded to the students' needs in a very short time.

Some characteristic key features of the new course include:

- *Elimination of large lecture*: Students now meet solely in small classes of 25-30 students. Homework, tests, and final grades are handled by central course coordinators, but each instructor is in charge of his or her students' learning. Among other benefits, the applied mathematics faculty aim to form "learning communities" within these small classes.
- *Active learning*: Students learn best when they themselves are actively engaged in the material, making sense of things for themselves rather than watching someone else do math. Lecturing is minimized in this course; instead, students are expected to read the text ahead of time, and the instructor then gives mini-lectures interspersed with students working on challenging problems in groups for the bulk of the time.
- *Use of a different text*: The course text is now *Functions Modeling Change: A Preparation for Calculus*. This text has a clear theme -- functions -- which immediately gives the course coherence. Furthermore, it is written with the expectation that students have seen all of the basic skills necessary in earlier classes; the focus here instead is on using those skills to treat mathematically interesting scenarios. There is a great deal of real-world data in the problems, and consistently functions are examined symbolically, numerically, graphically, and verbally (the so-called "Rule of Four.")

Overall, the applied mathematics faculty has found this new pre-calculus course to be more effective in enabling students to learn the skills they need to succeed in calculus. The small class sizes allow for more personalized attention to student needs. Moreover, this manageable size allow for effective active learning modules in class. Although student successes attributed to these items alone are difficult to measure directly, the applied mathematics faculty believes firmly in this restructured pre-calculus course.

4.1.B Developing Communication Skills

In the Spring of 2009, the applied math faculty inaugurated a one credit course (Math 91: Topics in Applied Mathematics) with the aim of developing the communication skills of the students. This course is aimed at sophomore students interested in applied mathematics. Through a variety of applied mathematics topics, it emphasizes the clear expression of mathematics. Students will work to improve their written expression in their homework assignments, which are graded as much for content as for form. The oral expression of mathematics is emphasized through a short student presentation on a subject of the student's choosing. After a positive response from the students, this class is being offered in Spring 2010.

4.1.C Calculus Textbook Adoption

The applied mathematics faculty decided early on to adopt a single textbook that would serve all of the calculus courses: Math 21, 22, 23 and 30. The original text was by Hughes-Hallet *et al*. For several reasons, the applied mathematics faculty and the students in these classes voiced concerns over this particular text. To respond to these concerns, the applied mathematics faculty met to evaluate several other textbooks after the Spring Semester of the 2006-2007 academic year. After several discussions, the applied mathematics faculty decided to use the text by Stewart. The applied mathematics faculty felt that this text aligns better with the goals and objectives of the calculus courses. The applied mathematics faculty has found that both students and faculty enjoy the use of this text. It has been the text for Math 21, 22, 23 and 30 ever since.

4.1.D New Calculcus Course Sequence (under review)

Dr. Lei, Yue, who serves currently as the applied mathematics faculty member who oversees the calculus courses, expressed an observation about our calculus students. By analyzing available student data, the applied mathematics faculty were able to confirm a consistent and significant divide between two major groups of students:

1. Students needing at most two semesters of single-variable calculus;
2. Students requiring vector calculus, linear algebra and differential equations.

These two groups of students have very different motivations and objectives for taking calculus due largely to their specific academic goals.

The applied mathematics faculty has found that reaching both groups of students effectively and helping them to achieve their educational goals in the existing Math 21 and 22 courses is becoming more and more challenging. For example, to focus on the needs of the first group of students to develop and practice their problem-solving skills needed to understand the fundamental concepts in calculus

requires time away from some of the technical details that are needed by students in the second group. On the other hand, preparing students in Math 21 and 22 for the material in Math 23 and 24 only serves the proportion of students who will go on to take those courses.

To address this problem, the applied mathematics faculty has proposed a new, two semester calculus sequence comprised of the courses Math 11: Calculus I and Math 12: Calculus II. These courses are under review currently. These two courses are designed to meet the needs of the first group of students listed above. Provided that this change is implemented, the faculty will remove the existing course, Math 30: Calculus II for Biological Sciences which will be replaced with Math 12. Consequently, Math 21 and Math 22 will be tailored to meet the needs of the second group of students listed above. The faculty is tentatively going to change the name of Math 21/22 to Calculus I/II for Physical Sciences and Engineering, respectively, since these courses serve those particular majors. Thus, the applied mathematics faculty proposes that those majors requiring at most two semesters of calculus take Math 11 and 12 and those majors requiring more than two semesters of calculus take Math 21 and 22.

4.1.E Reorganizing the Core Curriculum (under review)

After the first cohort of Applied Mathematical Sciences majors went through the core curriculum of applied mathematics courses, the applied mathematics faculty determined that this core required some reorganizing. In particular, with respect to PLO 1, the applied mathematics faculty found that students were having difficulty making the transition to working with the rigor required for upper level mathematics courses focusing on analytical methods. Students were not meeting the applied mathematics faculty's expectations. Through individual discussions with students, the applied mathematics faculty determined that students felt that the difficulty in the content changed too abruptly from the lower division courses to the upper division courses.

The applied mathematics faculty met in the summer of 2008 to discuss this matter. From this discussion, the applied mathematics faculty decided to reorganize their upper division core courses that focus on analytical solutions methods. In particular, the applied mathematics faculty reorganized the content across the entire core so that students could develop their analytical problem-solving skills more gradually and in a more natural progression.

In particular, the applied mathematics faculty paid more attention to the transition that students make from the lower division Math 24 course to the current Math 121 course. The new course sequence, which is under review currently, eliminates Math 121 and replaces it with a new course, Math 125 and eliminates Math 142 and replaces it with a new course, Math 126. The sequence of Math 24, Math 125 and Math 126 gives students a three-course sequence in which students build and develop skills for solving ordinary and partial differential equations. By having this three course sequence, students can build smoothly and continually their analytical problem-solving skills rather than having three disjoint courses. Included with these changes are pre-requisite changes to ensure this smooth and continuous progression through these three courses that has an appropriate inclusion of material learned from those pre-requisite courses.

4.1.F Capstone Modeling Course (under development)

To address PLO 3 at the mastery level, the applied mathematics faculty will develop a capstone course in mathematical modeling. This course will serve several functions. One such function is to provide a unique experience for the Applied Mathematical Sciences majors that include a series of activities

designed to enhance their knowledge and appreciation of applied mathematics while preparing them for entry into a graduate program or placement in government, industry and business. Other functions of this capstone modeling course include avenues to assess the program through projects, presentations, and research.

The applied mathematics faculty plans to develop a prototype for this course by Summer 2010. This development will include a sample of the current Applied Mathematical Sciences majors. These students will survey different modeling problems and help choose which problems may be relevant and interesting to future students. By Fall Semester 2012, the applied mathematics faculty plans to deliver this capstone course.

4.2 Assessment Methods

Overall, the applied mathematics faculty is pleased that their initial proposal for program learning outcomes seems still to be appropriate and correct. Probably the largest concern that the applied mathematics faculty had in this initial assessment was the lack of "coherency" in our assessment of the embedded questions. This lack of coherence indicates that the faculty does not yet share a common understanding of what a particular level of performance looks like. Most likely, this occurrence was due to a lack of discussion about the initial rubric the faculty has developed. To that end, the applied mathematics faculty has decided to proceed differently in the future in at least the following two ways.

1. The applied mathematics faculty will do assessments of embedded questions in the future as a group so that they can have an open dialogue about our criteria and standards for evaluating student work.

2. The applied mathematics faculty will adopt a different evaluation methodology based on the holistic grading approach that many of us use for grading student work (see Section 7.8 for a description of Holistic Grading).

3. The applied mathematics faculty will seek more staff support for these assessments. In particular, the assessment reported on here could have been improved vastly by organizing the evidence collected better. By organizing this evidence collection and analysis effort better, the applied mathematics faculty believes that they can take full advantage of the entire group of faculty and suggest changes in real-time leading to a more meaningful discussion.

In these ways, the faculty feels that they are making changes to our approach to assessment that will lead to a proper calibration in which individual faculty draw conclusions reliably about the quality of student work.

5 Implications of proposed changes

To conduct future assessments and carry out the plans above, the Applied Mathematical Sciences program will require several resources. Many of these resource needs are under consideration or under development within the School of Natural Sciences, the Center for Research on Teaching Excellence and Institutional Planning and Analysis.

A critical component of all future assessments is evidence collecting. For the past several years, the applied mathematics faculty benefitted from the work of Ms. Cheryl Hedges, who acted as Math

Coordinator. Ms. Hedges collected student data from all of the lower division mathematics courses and produced a summary of analysis of that data. The applied mathematics faculty used that data each semester to conduct meetings and make plans for the following semester. This data and analysis was critical for the applied mathematics faculty to consider changes to the curriculum as well as in designing more formal assessments to investigate concerns more deeply. Unfortunately, Ms. Hedges moved on from that position and it remains unfilled due to the current fiscal situation. However, School of Natural Sciences' Dean Pallavicini saw the need for this kind of data collection and analysis for all of the programs within the School of Natural Sciences. Consequently, she has been allocating staff support to help the programs within the school, including Applied Mathematical Sciences, continue their routine data collection and analysis. An important area where this data collection and analysis will be crucial is for the lower division service mathematics courses, especially with the ever-growing students needing Math 5: Pre-calculus and even more fundamental mathematics skill building. The implications of assessments made by the Applied Mathematical Sciences program on these lower division courses are far-reaching in that they affect several other programs on campus. As a result, these assessments will have to be done in cooperation and coordination with those other programs. The applied mathematics faculty hopes that their colleagues in other programs will help in this coordination.

The Center for Research on Teaching Excellence has provided a great deal of support already to the Applied Mathematical Sciences program assessment. They have helped to organize this initial assessment including organizing and coordinating the student focus group meeting. The applied mathematics faculty values greatly the work that this center does for this program. As the applied mathematics faculty prepares to conduct future assessments, they will look even more to this center for help and support.

There have been some initial discussions between the applied mathematics faculty and staff from Institutional Planning and Analysis. The applied mathematics faculty is hoping to collaborate with Institutional Planning and Analysis to create a dynamic database of student data – a larger scale version of the data collection, analysis and summarizing that Ms. Hedges did earlier. This larger scale effort is crucial for addressing the lower division mathematics courses that affect the entire campus.

The major challenge in addressing the future assessments lies in coordinating all of this data collection and analysis coming from different offices. Ultimately, this work is the responsibility of the applied mathematics faculty. To that end, the applied mathematics faculty has reorganized themselves to address these and other matters. Although the applied mathematics faculty values this assessment work, it does come at the very real and substantial cost of time away from other scholarly duties. The balance of faculty effort needed to do this work while maintaining productivity in scholarship continues to be a challenge that remains insufficiently addressed by this university.

6 Self evaluation

Using the "Rubric for the Report on PLO Assessment," the applied mathematics faculty self-evaluate this program according to the results of this initial assessment.

6.1 Assessable Program Learning Outcomes

The faculty agree strongly that the current program learning outcomes represent a good first attempt at encapsulating a practical realizable set of outcomes for their expectations of students in the program. The language used to articulate these outcomes emphasizes correctly that the applied mathematics

faculty are dedicated to enabling students to become effective problem-solvers versed well in both analytical and computational methods (PLO's 1 and 2). The faculty agree that solving an applied mathematics problem requires a broad view that includes a strong knowledge-base of the application area to which the solution serves (PLO's 3 and 5). And finally, the faculty is committed to teaching students effective communication skills that are essential for presenting findings and results to the broadest possible audience so that their work can have the most impact possible (PLO 4).

The initial assessment presented here has provided the applied mathematics faculty a beneficial test of their program learning outcomes. Overall, the applied mathematics faculty agrees still that the program learning outcomes are reasonable and appropriate. However, the applied mathematics faculty has learned a great deal about their specific expectations of students through this assessment exercise. In particular, the applied mathematics faculty has revised their explicit criteria in the course rubrics. This revision will undoubtedly lead to new approaches in teaching that enable students better to fulfill the program learning outcomes.

6.2 Valid Evidence

Collecting and evaluating embedded questions is clearly the most sensible choice for evidence. This evidence provides the applied mathematics faculty a direct line to students' abilities and skills. At the same time, the student focus group provided valuable insight into students' perceptions of the program learning outcomes that the applied mathematics faculty did not always anticipate. The combination of these direct and indirect methods for collecting evidence proved to be essential for a comprehensive initial assessment.

The major challenge in acquiring valid evidence for assessment is probably the sample size. The Applied Mathematical Sciences program is not a big program. Moreover, this program is still in its infancy. Thus, the faculty must work with small sample sizes that may not be appropriate for extrapolating to a broad view of this program. On the other hand, the applied mathematics faculty enjoys this current situation in which they have the ability to work with students on an individual basis. Again, the applied mathematics faculty feels strongly that this situation has led to the student statement in the focus group discussion that "faculty were always available to help." It will become clearer as the faculty conduct future assessments that their view of the evidence will take on a broader view because the program will grow.

6.3 Reliable Results

Since this report discusses our very first formal assessment of the Applied Mathematical Sciences program, the applied mathematics faculty is still developing a collective understanding of the standards in evaluating the program. Just by reflecting on the revision of the rubric used to evaluate the embedded questions, the applied mathematics faculty has reached a new understanding that this calibration process will be dynamic and on-going. Certainly, this initial assessment provided the means to begin this discussion.

6.4 Summarizing Results

An important issue that the applied mathematics faculty will take on in the near future is communicating their assessment results on their lower division service courses to the other programs to whom those courses serve. The faculty hopes to develop a collaborative effort in which faculty and students from other programs participate in this very large assessment effort. Moreover, the faculty

hopes that in conducting this assessment, they can achieve even more alignment with the goals of other programs on campus, thereby strengthening the overall mission of this university.

6.5 Conclusions and Recommendations

The applied mathematics faculty is fortunate to have a student body who participated actively in this initial assessment. Because of this participation, the applied mathematics faculty was able to derive a great deal of information from this initial assessment. Indeed, student participation is essential for meaningful assessment. For future assessments, the applied mathematics faculty will develop concrete incentives for student participation. The applied mathematics faculty is dedicated to conducting transparent assessments to which students, faculty and staff have access. To that end, the applied mathematics faculty will develop more inclusive methods for conducting assessments that encourage more participation and yield a deeper sense of ownership among the stakeholders of this program. A critical component of this endeavor will be opening up communication channels and extending dialogues with students, staff and faculty. The applied mathematics will be developing methods for achieving these goals in the near future.

7 Appendices

7.1 Summary of Meeting on August 26, 2009 between Arnold Kim, Mike Roona and Anne Zanzucchi

<u>Overview</u>

The beginning of our meeting focused on a draft of the rubric for PLO #1, developed during Spring 2009. The original plan included assessing embedded questions in Math 22: Calculus II, Math 24: Introduction to Linear Algebra and Differential Equations, and Math 131: Numerical Analysis to create and refine assessment rubrics. These three courses were selected for review as on the Curriculum Map they represent the full range of abilities (introduction, develop, mastery).

Part of our discussion explored some potential challenges with a rubric covering so many levels of skill and coursework. Arnold emphasized the importance of faculty buy-in with assessing student work and developing this rubric, so the assessment task and results should have a high-level of applicability. With that in mind, it was suggested that the scope of assessment could be narrowed and thereby gain depth and faculty engagement.

Since Math 131 is a course that has been discussed frequently by faculty and serves as an important gateway and also is a course that will play a key role in the assessment of PLO #2 and PLO #3, initially focusing on this course seemed ideal. In addition, the suggestion was made that it might be easier to move the assessment process forward by focusing on MATH 131's role in the development of computational methods (PLO #2), rather than analytical methods (PLO #1).

Student coursework would need to be discussed by faculty during Fall 2009 to prepare the January 2010 annual report, so we discussed some strategies for evaluating advanced homework sets to develop a shared rubric and strategize curriculum changes (as needed).

<u>Institutional Planning & Analysis Support</u>

Surveys: Five surveys were provided, three locally developed (New Undergraduate Survey, Graduating Seniors Survey, and Alumni Survey), one UC-wide survey (UCUES) and one national survey (NSSE). The UCUES and NSSE surveys have been administered at UCM in alternate years (in the spring semester). The UCUES and NSSE surveys allow for comparisons, by program, with other institutions (UC campuses or other colleges/universities nationally).

Timeline

29 Sept. – 1 Oct. 2009: Capacity & Preparatory Review Site Visit
15 Jan. 2010: Summary of PLO 1 Assessment (to WASC Steering Committee)
15 Mar. 2010: Summary of Program Assessment (to WASC Steering Committee)
14 Dec. 2010: Educational Effectiveness Report
8-10 Mar. 2011: Educational Effectiveness Review Site Visit
June 2011: Initial Accreditation expected

7.2 Summary of Meeting on November 12, 2009 between Arnold Kim and Anne Zanzucchi

Our meeting focused on potential overlaps between the assessment aspects of program review and FAO annual reporting on student learning outcomes. We discussed an assessment plan for December that will lead to direct and indirect evidence of learning, related to PLOs 1 & 2:

> Upon graduating, we expect students completing the Applied Mathematical Sciences major to have become effect *problem-solvers*, meaning that student will be able to
>
> 1. Solve mathematical problems using analytical methods.
> 2. Solve mathematical problems using computational methods.

The aim of this assessment plan is to refine a currently rough draft of a rubric that outlines criteria and standards for analytical and computational methods. Embedded questions have been collected for both of these PLOs and could be rated according to this rubric, ultimately with the intention of developing the rubric further. The revised rubric, then, will function as a guideline for describing expectations to students and providing a common vocabulary among faculty to describe student progress.

Prior to a December faculty meeting, MATH faculty will receive a set of 6 embedded question responses which they will evaluate on their own time. A Word.doc evaluation form will be sent to Math's staff support, who will save files in folders labeled Exemplary, Satisfactory, Poor to tabulate scoring trends. This form will include a narrative commentary box, asking:

(1) What overall features from the rubric helped you rate the quality of this student response?
(2) Are there features not described in the rubric that would be useful to include? Please describe

A CRTE staff member can work with Math's staff support member to analyze this narrative data. In the December faculty meeting, participants will work in pairs for calibration and dialogue purposes. The rubric will be refined and shared, based on the prior work of rating samples. Pairs of faculty will then rate student work again using the refined rubric and provide similar feedback on its development. Of interest will be to see if the scoring patterns are relatively similar once faculty work together on conclusions and apply a more detailed rubric.

For indirect evidence, faculty could be asked to describe their expectations of what students are able to do with this PLO before rating samples. Then, they could reflect on whether there are any differences in their expectations after reading samples.

Students in MATH 131 / 121 could complete a survey asking for their responses to the PLO. A focus group could be conducted in March 2010 to see the extent to which their predictions about how the courses would apply to their major were accurate. A sample focus group session script is attached.

7.3 Agenda of Applied Mathematics Faculty Meeting on December 7, 2009

1. Announcements [5 min]
2. Reports
    a. Hiring (Arnold) [10 min]
    b. Graduate Program (Mike) [10 min]
    c. Undergraduate Program (Francois) [10 min]
    d. Lower-division service (Lei, Yue and Arnold) [10 min]
3. Assessment for WASC [15 min]
4. University Program Review [20 min]
5. New Business [5 min]
6. Adjourn

No meeting minutes are available to include in this report.

7.4 Initial Rubric for Assessing PLO 1 for Math 121 Embedded Homework and Final Exam Problems

Poor	• Little evidence of drawing on relevant previous knowledge is present, showing little relevant engagement in the task • Some correct reasoning or justification for reasoning is present with trial and error, or non-systematic trying of several cases • There is an incomplete explanation, it may not be presented clearly • The solution is not complete indicating that parts of the problem are not understood
Fair	• Evidence of drawing on some relevant previous knowledge is present, showing some relevant engagement in the task • Planning or monitoring of strategy is evident, which leads to a solution of the problem • There is a clear explanation and appropriate use of accurate mathematical representation with few errors • The solution shows the student has a broad understanding of the problem and major concepts. Arguments are constructed systematically
Good	• Adjustments in strategy, if necessary, are made along the way and/or alternative strategies are considered • As systematic approach and/or justification of correct reasoning is present. This may lead to 1) clarification of the task, 2) exploration of mathematical phenomena and 3) noting patterns and structures • Appropriate and accurate mathematical representations are constructed and refined to solve problems or communicate the solution

7.5 Initial Rubric for Assessing PLO 2 for Math 131 Embedded Homework and Final Exam Problems

Poor	• Little evidence of drawing on relevant previous knowledge is present, showing little relevant engagement in the task • Some correct reasoning or justification for reasoning is present with trial and error, or non-systematic trying of several cases • Unsuccessful or incomplete transfer analytical knowledge to algorithm development, implementation and testing • There is an incomplete explanation, it may not be presented clearly • The solution is not complete indicating that parts of the problem are not understood
Fair	• Evidence of drawing on some relevant previous knowledge is present, showing some relevant engagement in the task • Planning or monitoring of strategy is evident, which leads to a solution of the problem • Successful and complete transfer analytical knowledge to algorithm development, implementation and testing • There is a clear explanation and appropriate use of accurate mathematical representation with few errors • The solution shows the student has a broad understanding of the problem and major concepts. Arguments are constructed systematically
Good	• Adjustments in strategy, if necessary, are made along the way and/or alternative strategies are considered • Attention paid to gaining efficiency in algorithm implementation through testing and validation • As systematic approach and/or justification of correct reasoning is present. This may lead to 1) clarification of the task, 2) exploration of mathematical phenomena and 3) noting patterns and structures • Appropriate and accurate mathematical representations are constructed and refined to solve problems or communicate the solution

7.6 Summary Report of Student Focus Group Discussion held on January 19, 2010

Number of Participants: 6 students

Goal: The focus of this session is to determine key responses to students' learning experiences in the major program. The interview concludes with a problem-solving opportunity to ensure constructive and applicable feedback.

Brainstorming

Take about 2-3 minutes to list or write a brief paragraph about your primary experiences as an Applied Mathematics student. What are the immediate images, concepts, or phrases that come to mind?

Illustrations and Applications:

The students agreed that there should be more illustrations and interactive applications of the concepts they were studying in the math class. They suggested having an assignment/ a class focused solely on connecting the math to real life situations, such as a long term project. One student stated, "it is hard to

remember any of the material if it is not immediately applied to something, because it has no meaning if remembered by itself".

Material:

There were mixed feelings about the programs. One student felt that the Mat Lab program was not introduced to them properly or completely, and this hindered their ability to operate in the class, and they should not have wasted time in Java for their prerequisites. On the other hand, another student had ease with the program, and thought Java was better to learn than Mat Lab because of its flexibility. The other three students were indifferent on the subject and had no comments on the matter. It was also suggested to have more integration of programs such as "Latex" which would help better prepare them for graduate school as well as writing papers for the Mathematics community in the future.

Writing Class:

Another suggestion was to have a writing 116 class more geared towards writing in Math as opposed to writing in biology. Two of the students felt that they were unable to write in the correct format because the writing class was primarily for Biology students. They felt that they were not receiving a fair writing education in the Math major.

Students' experience & Assignments:

Students felt Math 131 and 121 professors are engaging since they are eccentric and entertaining, but that students were often given large amounts of notes and homework and short time for completion. The students request to be given more time to complete Math 121 assignments which take much longer to complete than the time originally assigned.

Program Learning Outcomes

Given these PLOs, how applicable has Math 131/121 been to the next step in your Applied Mathematics Major?

- Solve mathematical problems using analytical methods.
- Solve mathematical problems using computational methods.

The general consensus was that the program is definitely moving in the right direction, but the students do not feel completely confident in being able to do either of the analytical or computational methods yet. The group expressed that the program focuses much more strongly on analytical rather than computational methods.

One student felt that the Math 131 & 121 classes were a good start in upper division courses, and they were able to establish the expectations of the program. The Math 121 class was very helpful in progressing the analytical PLO, and Math 131 helped a little bit in the analytical PLO but was mainly iterative.

Students' engagement & Curriculum

At what point did you really feel as though you were fully engaged with Applied Mathematics? The group felt that Math 141 was their turning point as an Applied Mathematics student, and suggested that

it should be taught earlier because it enabled them to know how to solve any math problem. However, one student suggested that "Transforms" from Math 121 was the real engaging point alongside with the Math 131 homework which made the students feel they really understood the material.

Teaching Practices

Have there been teaching practices that have been particularly effective at supporting your learning?

Participant agreed that professor Harish Bhat, who didn't adopt a book in Math 121 and posted extensive but very instructive and easy to follow notes on CROPS, taught the class with such great understanding that the students praised his methods excitedly. Similarly, Math 131 professor made an attempt to show applied, "hands on" learning which also aided the students' learning. The students agreed that these methods were extremely effective and helped their learning.

Conclusion

Key points that the faculty should know:

The students would like to ask faculty to be a little more patient with them because they felt that the professors did not seem to understand how difficult the subject was to them, and also they appreciated the fact that faculty were always available to help, and it should stay that way.

7.7 Agenda of Applied Mathematics Faculty Meeting on January 23, 2010

1. Announcements
2. Discussion
    a. Gather individual feedback on the assessment
    b. Determine initial results on student performance
    c. Gather feedback on Student Focus Group summary (see attachment)
3. Presentation of Assessment Data
    d. Discuss the cumulative results
    e. Reflect on initial results in light of the data
4. Revisit the rubrics
    f. Determine revisions needed to ensure more consistent assessment in the future
    g. Propose future studies for assessment
5. Discussion
    h. Next steps for future assessments
    i. Implications of these results in our program review
6. New Business
7. Adjourn

No meeting minutes are available to include in this report.

7.8 Holistic Grading

Holistic grading is a method for assessing student work. Dr. Bruce Birkett, a consultant for the School of Natural Sciences during the 2005-6 and 2006-7 academic years introduced holistic grading to the applied mathematics faculty. Below is a reprint (with their kind permission) of a document that Dr. Birkett and his colleague, E. Alby wrote to explain it.

What is holistic grading?

Don't worry: the touchy-feely sounding name actually refers to a well-established grading technique designed to assign more meaningful scores. Instead of "reductionistically" grading the students' answer line by line, you read the solution as a whole and evaluate the students' overall level of understanding of the concepts and problem-solving techniques. Although this method sounds vague, it yields *very* reliable results, when done properly. (In education jargon, "reliable" means that different graders would agree upon the score, making the score more meaningful.) Indeed, ETS uses exactly this method to grade AP exams for this reason.

What's wrong with traditional grading?

In traditional grading, you break up a problem into pieces, and assign a point value to each piece. Students lose points for each piece that they get wrong. For instance, in a block-on-a-ramp problem, students might lose 2 points for getting the normal force wrong, 3 points for resolving the gravity vector incorrectly, and so on. A majority of the time, this system yields a fair score. But you also get some very perverse results. For instance, graders have given students only 5 or 6 points out of 10 even when their presentations showed a clear understanding of the material, because many small errors chipped away at their scores. At the same time, other students have gotten 8 or 9 out of 10 points because they blindly got all the pieces of the problem right, even though they clearly had no clue about how those pieces fit together, except by rote.

Holistic grading avoids these perverse outcomes, because it focuses on the student's overall answer, not on the pieces of the answer. Most of the time, holistic grading and traditional grading give similar results. But holistic grading yields better results in the kinds of cases just discussed. And it's faster than traditional grading, because you get less bogged down in details.

How does holistic grading work?

In holistic grading, you typically give the students' answer a score between 0 to 5, where...

5 = excellent understanding. "He's got it!" The student clearly understands how to solve the problem. Careless errors can appear on a "5" paper, provided the errors don't indicate a conceptual misunderstanding or lead to an entirely unphysical result. Typically, you can tell a "5" within ten seconds of looking at it—and even faster, after you've seen lots of them.

4 = good understanding. "She has the basic idea, but messed up on one thing..." The student understands the main concepts and problem-solving techniques completely or almost completely, but still has some minor yet nontrivial gaps in her reasoning. If you were tutoring this student, you wouldn't need to go back to basics. You'd just need to address the one or two "sticking

points."

3 = fair understanding. "He's partly getting it, but missing some important stuff." The student isn't completely lost, but doesn't really get it, either. If you were tutoring this student, you'd have to go back to some of the basics, but you wouldn't need to dwell on them. A "3" answer often looks like the student was going along fine for a while, but then branched off in some weird direction, or just didn't know how to handle a crucial step. Part of the answer may look like it was done more by rote than by really understanding.

2 = poor understanding. "Everything's done by rote; she doesn't understand what she's doing." A "2" answer isn't *completely* off base. But it reflects reasoning done almost entirely by rote memory or by "pattern matching" to an earlier problem. Or maybe the student goes off in some direction that's not entirely crazy, but doesn't work.

1 = no understanding. "He didn't get it at all." The student may have jotted down some appropriate formulas and diagrams, but didn't know what to do with them. Or he did something *completely* off base.

0 = wrote hardly anything. "She left it blank." Even blatantly wrong or incomplete answers get a 1. A 0 is reserved for blank or almost-blank pages.

With help from the professor or from another TA, you should find some student answers that fit squarely into each category. Use these answers as "calibration." This is really important; holistic grading is reliable only when you have good benchmarks for each of the 5 gradations.

To grade efficiently using this system, the key thing is to escape the mindset of assigning "points off" to particular mistakes. Of course, answers containing the same mistake often end up with the same score. But even so, you should look at how that mistake fits into the overall reasoning.

Important: If the problem is worth, say, 30 points, you'll probably find yourself wanting to use more than 5 gradations. Instead of giving all answers a score of 0, 6, 12, 18, 24, or 30, you might decide that someone deserves a "high 3/low 4," i.e., a score of 21. If you do this occasionally—no more than 10% of the time—then it's fine. But by doing it too frequently, you essentially end up with 10 gradations instead of 5, which reduces the reliability of holistic grading. To maintain reliability, please interpolate between the 5 gradations only when you feel you *must*.

Borderline cases

Sometimes you'll have a really hard time deciding a score. Most of the time, you should trust yourself and go with your gut feeling. But in the few cases where you just can't decide, go ahead and ask another TA or professor to act as your tiebreaker. And you can be someone else's tiebreaker.

Analyses of Fall 2007 Lower Division Mathematics Courses at UC Merced

Prepared by Cheryl Hedges

January 16, 2008

In Brief

Points of interest in this document are summarized in brief below. You can find a more detailed analysis of all fall courses in the following section.

- In Math 5, 42.7% of 110 students failing at mid-semester were able to improve grade to ñC-ò or better.
    - Gateway Exams, tutoring services, and academic workshops aided in this improvement.
        - Students continuing on to Math 21 at UC Merced will be tracked to review how well Math 5 prepares students for Calculus I. In addition, monthly math faculty meetings will be held during spring 2008 to discuss issues surrounding the Math 5 to Math 21 transition.

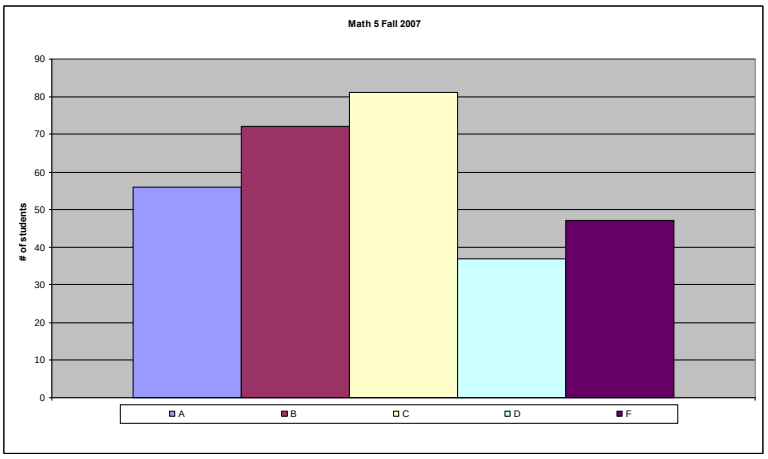
- 45% (68/151) of students failed Math 21.
    - Early assessment exam shows 78.1% (25/32) of students failing exam failed Math 21.
    - Viewing discussion participation scores shows no one receiving less than 80% of discussion points (36 students) received higher than 60% of total possible points.
    - 92.5% (37/40) of students failing at mid-semester failed Math 21.

Course Analyses

The applied mathematics faculty has asked for analyses of mathematics courses offered during the fall 2007 term at UC Merced. Data received from math instructors and the Office of the Registrar is summarized below. For the purpose of this document, a ñpassingò grade is defined as ñC-ò or better in the course.

- Math 005 ï 71.3% (209 of 293) student passed.
- Math 021 ï 55.0% (83 of 151) students passed.
- Math 022 ï 76.9% (93 of 121) students passed.
- Math 023 ï 66.1% (37 of 56) students passed.
- Math 024 ï 74.4% (35 of 49) students passed.
- Math 030 ï 85.2% (23 of 27) students passed.
- Math 032 ï 97.4% (74 of 76) students passed.

Math 5 – Preparatory Calculus



Overview

The chart above shows the final grade distribution for Math 5. Of the 293 students enrolled at the end of the fall 2007 term, 71.3% received an A, B, or C which is similar to the 2006 ï 2007 academic year average of 72.5%.

At mid-semester, 62.8% (110 of 296) were receiving a D or F. Of those 110 students, 47 (42.7%) were able to improve their grades to a level of passing.

Math Placement Exam

Students entering UC Merced in fall 2007 were required to take a 25-question online, non-proctored calculus readiness exam administered by Maple T.A. A student scoring 20 or more is placed into Math 21, Calculus I, while those scoring 19 or less are recommended to enroll in Math 5, Pre-Calculus. The chart below compares studentsô placement score to final Math 5 grade.

Placement Score	n	A, B, C	D, F
20 to 25	3	3 (100%)	0
17 to 19	62	55 (88.7%)	7
11 to 16	98	76 (77.6%)	22
1 to 10	53	27 (50.9%)	26

The Maple T.A. placement exam and 20-score cut-off appear to be achieving acceptable results.

Gateway Exam

Math 5 Gateway Exams were administered for the first time this term, fall 2007. These exams test algebraic and computational skills students should have attained in high school and will be built upon during Math 5. Passing the exam does not increase a studentôs grade; however, failing to pass the exam will decrease a studentôs grade by 1/3. The results of the exam are as follow:

- 217 students passed.
- 66 did not pass.
- 20 did not attempt.

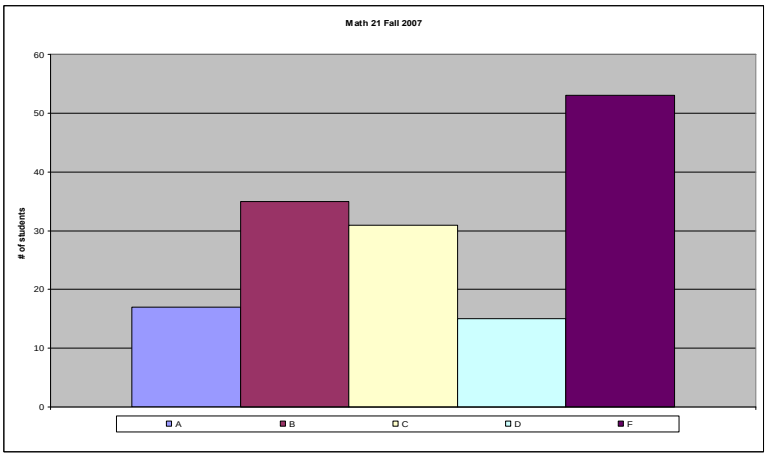
Of the 66 who did not pass, we obtain the following results.

- 3% (2) received an A+, A, or A-.
- 7.6% (5) received a B+, B, or B-.
- 30.3% (20) received a C+, C, or C-.
- 56.1% (37) received a D or F.
- 3% (2) withdrew from course.

The gateway exam is adequately identifying students needing review of fundamental Pre-calculus skills. Earlier completion of the gateway exam will allow more time to address those deficiencies and progress through the semester.

During fall 2006, only 5.7% (2/35) students failing at mid-semester were able to improve their grade from a D or F to a C- or above, compared to 42.7% (47/110) in fall 2007. Anecdotally, a combination of administering the gateway exam, improved student services such as tutoring, and academic workshops all played a role in this improvement.

Math 21 – Calculus of a Single Variable I



Overview

The chart above shows the final grade distribution for Math 21. Of the 151 students enrolled at the end of fall 2007 term, 55% (83) received a letter grade of A, B, or C. The average pass rate for the 2006 ï 2007 academic year was 63%.

At mid-semester, 44 students were receiving a grade of D or F in Math 21, only 40 of which could be identified at end of semester. Of those 40 identified as receiving D or F at mid-semester, 37 received a D or F as a final grade. Therefore, 92.5% (of 40) failing at mid-semester, failed the course. Math 21, Calculus I, is often seen as a transition course. The subject matter is challenging and constantly builds upon previously learned topic. Once a student falls behind, it is often difficult to recover; however, it is not impossible. Early, reliable assessment can help identify students in danger of falling quickly behind.

Assessment

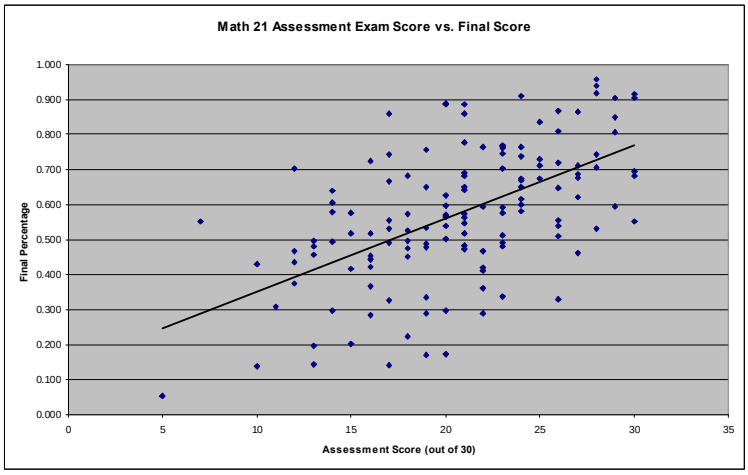
The first step in assessment is given to incoming students as the Math Placement Exam. Students entering UC Merced in fall 2007 were required to take a 25-question online, non-proctored calculus readiness exam administered by Maple T.A. A student scoring 20 or more is placed into Math 21 while those scoring 19 or less are recommended to enroll in Math 5. The chart below compares studentsô placement score and final Math 21 grade.

Scores on the Maple T.A. Math Placement Exam in Relation to
Math 021 Final Grade Fall 2007

	Final Grades					
Placement Test Score	0 F	1 D	2 C	3 B	4 A	Total n
17		1	1			2
18				1	1	2
19	1	1		1		3
20	4	2	5	3		14
21	5		3	6	2	16
22	2		4	3	1	10
23	2		3	5	5	15
24	1	1		4	3	9
25	2	1			2	5
Total	17	6	16	23	14	76
%	**22.4**	**7.9**	**21**	**30.3**	**18.4**	**100**

A weak, but positive correlation ($R^2 = .0451$) between placement and final grade was found, with an average grade of 2.16 for freshmen students. It appears that a score of 20/25 is the pivot point and an adequate cut-off.

The second step of assessment is given as a 30-question diagnostic exam administered at the beginning of the semester by Dr. Michael Sprague. Below are the results correlating studentôs assessment exam score to final score.



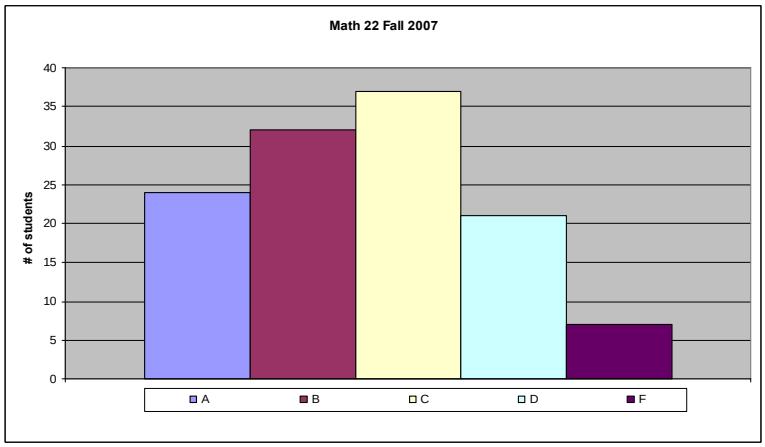
A linear regression computed positively correlates with the final scores ($R^2 = 0.32$).

Of the 151 students enrolled at the end of the term,

- 33.1% (35/106) students scoring 17 or more on assessment failed course.
- 78.1% (25/32) students scoring below 17 failed course.
- 13 had no score.

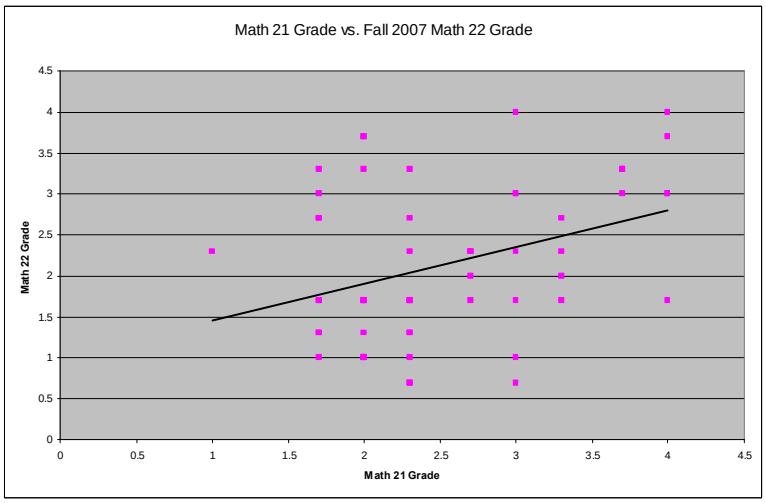
It appears that statistically, a student with a score of 16 or less will fail the course. A score of 17 or more is statistically inconclusive but suggests that a student has the fundamental skills needed to succeed in Math 21. However, this is only a portion of the puzzle for success, with the main portion relying on discipline and effort.

Math 22 – Calculus of a Single Variable II



Overview

The chart above shows the final grade distribution for Math 22. Of the 121 students enrolled at the end of the fall 2007 term, 76.9% (93) received a letter grade of A, B, or C.

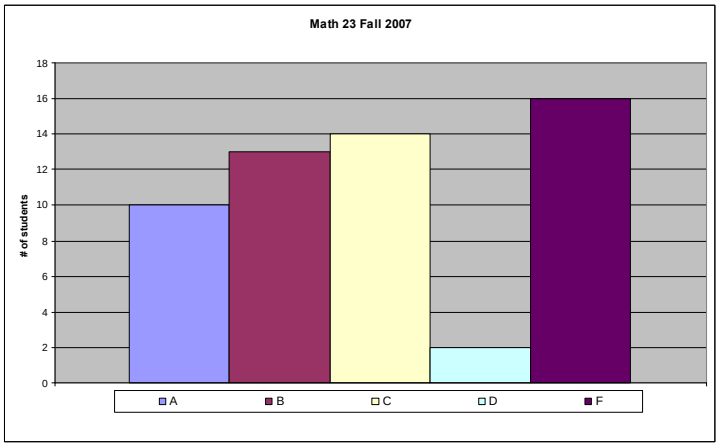


A linear regression computed positively correlates with studentsô fall 2007 Math 22 course grade ($R^2 = 0.1289$).

Math 22 (Calculus of a Single Variable II) is comprised of three categories of students: students passing Math 21 (Calculus of a Single Variable I) at UC Merced, students passing ICP 1 (Integrated Calculus and Physics) at UC Merced, and students who completed Calculus I at another institution. The fall 2007 term is as follows:

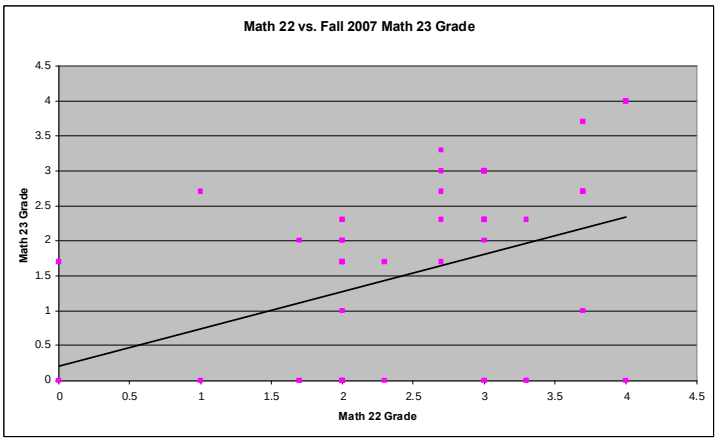
- 57 previous Math 21 at UC Merced students, 15 which failed (26.3%)
- 33 previous ICP at UC Merced students, 11 which failed (33.3%)
- 31 completing Calculus I at other institution, 2 which failed (6.5%)
- 45 students repeating Math 22, 10 which failed (22%)
    - 20 are previous Math 21 students
    - 25 are previous ICP 1 students

Math 23 – Vector Calculus



Overview

The chart above shows final grade distribution for Math 23. Of the 56 students enrolled at the end of the term, 66.1% (37) of students received a letter grade of A, B, or C.

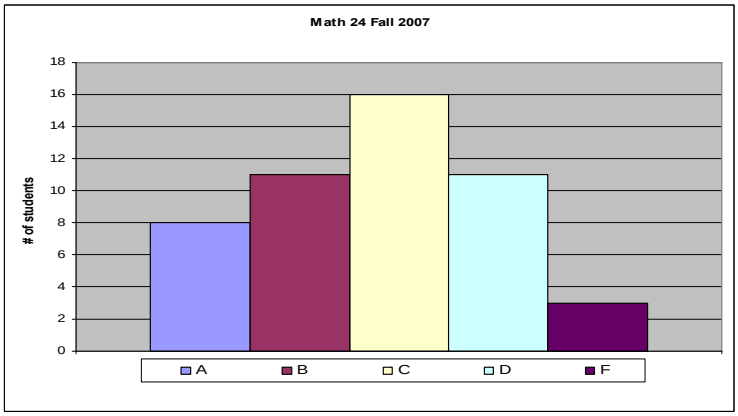


A linear regression computed positively correlates with fall 2007 Math 22 grade (R^2 = 0.144).

Fall 2007 Math 23 student history is as follows:

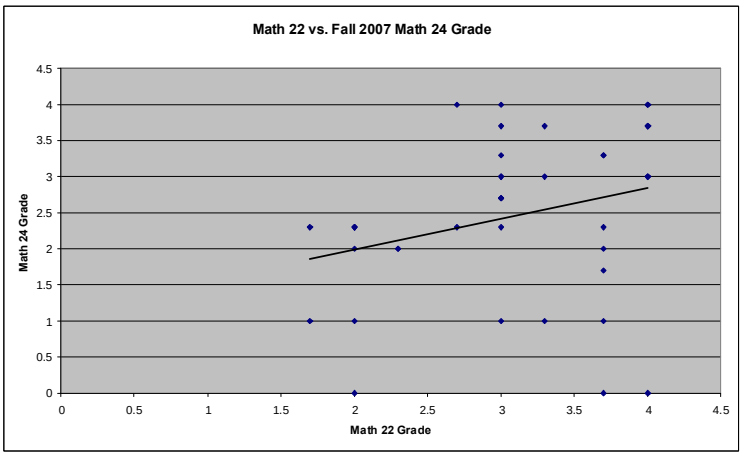
- 48 of the 56 enrolled previously took Math 22 at UC Merced
- 8 students completed Calculus II at other institution
- 7 students repeating Math 23

Math 24 – Linear Algebra and Differential Equations



Overview

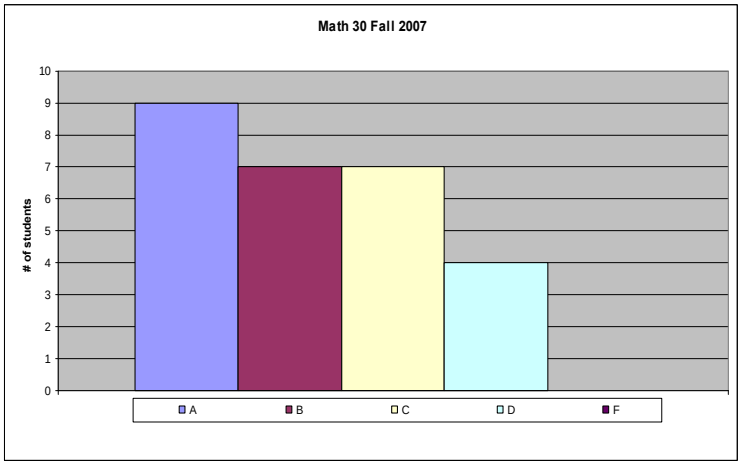
The chart above shows final grade distributions for Math 24. Of the 49 students enroll at the end of the term, 74.4% (35) of students received a letter grade of A, B, or C.



A linear regression computed positively correlates with fall 2007 Math 24 grades, although correlation is not strong (R^2= .0769).

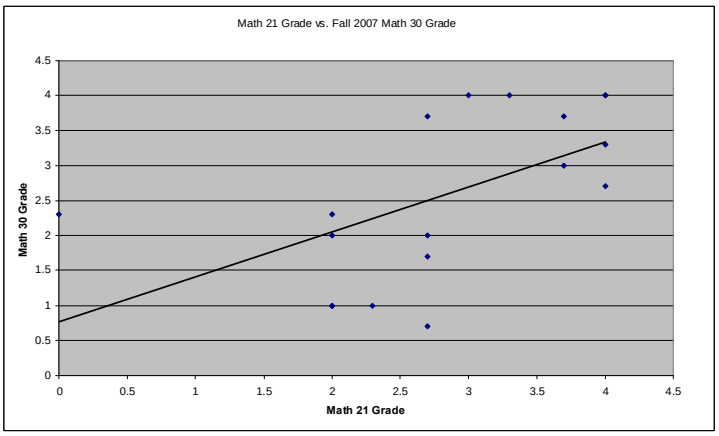
The grades earned in Math 22 correlate more to grades earned in Math 23 than in Math 24.

Math 30 – Mathematical Biology



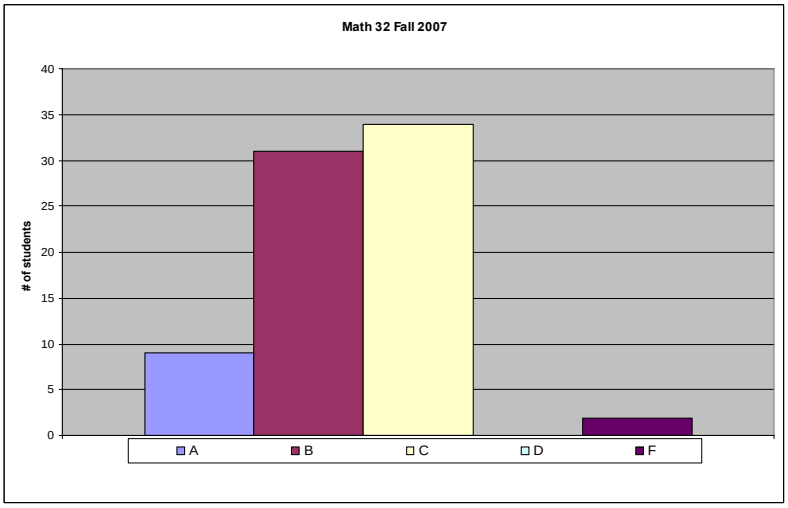
Overview

The above chart shows the final grade distribution for Math 30. Of the 27 students enrolled at the end of the term, 85.2% (23) of students received a letter grade of A, B, or C.



A linear regression computed positively correlates with Math 30 grades ($R^2 = 0.3178$).

Math 32 – Probability and Statistics



Overview

The above chart shows the final grade distribution for Math 32. Of the 76 students enrolled at the end of the term, 97.4% (74) of students received a letter grade of A, B, or C.

Spring 2008 Lower Division Mathematics Course Summary at UC Merced

Prepared by Cheryl Hedges

June 5, 2008

In Brief

Points of interest in this document are summarized in brief below. You can find a more detailed analysis of all spring courses in the following section.

- Average grade point is higher in fall than in spring for each course other than Math 21, which had an anomalously low pass rate during the fall. What techniques can we employ that will help maintain focus and effort during spring term?
- Math 5 pass rate is anomalously poor – 43.4% of 129 enrolled passed course.
  - 41 students repeating Math 5 from fall 2007
    - 24 failed.
  - 49 students did not pass gateway exam
    - 41 of which failed course.
  - Low attendance to office hours and tutorials.
- Previous Math 5 students performed very well in Math 21 – 80.5% of 149 enrolled passed course.
- Math 23 abnormally low pass rate – 48.2% of 56 enrolled passed course.
  - 15 students took Math 22 more than once.
  - 18 students are in "poor academic standing."

Spring 2008 Course Overviews

What follows is an overview of lower division mathematics courses at UC Merced for the spring 2008 term. For the purposes of this document, a "C-" or better is considered "passing."

- Math 005 – 43.4% (56 of 129 students) passed.
- Math 021 – 76.1% (162 of 213 students) passed.
- Math 022 – 73.5% (100 of 136 students) passed.
- Math 023 – 48.2% (27 of 56 students) passed.
- Math 024 – 75.3% (58 of 77 students) passed.
- Math 030 – 93.3% (28 of 30 students) passed.
- Math 032 – 86.3% (69 of 80 students) passed.

Table 1. 2007 – 2008 academic year enrollment, pass rate, and grade average summary of lower division mathematics courses.

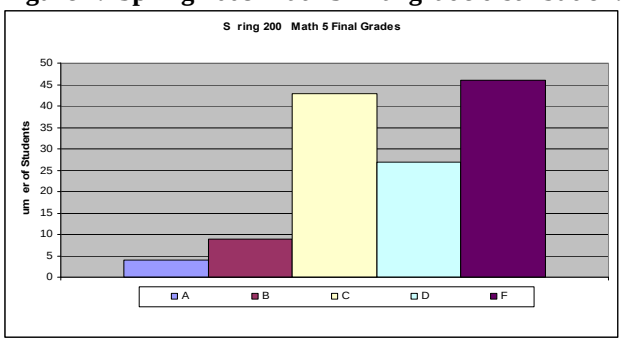
Course	Amount Passing Fall 2008	Fall 2007 Average Grade Point	Amount Passing Spring 2008	Spring 2008 Average Grade Point
Math 5	71.3% of 293	2.16	43.4% of 129	1.18
Math 21	55.0% of 151	1.68	76.1% of 213	2.05
Math 22	76.9% of 121	2.14	73.5% of 136	2.09
Math 23	66.1% of 56	1.95	48.25% of 56	1.57
Math 24	74.4% of 49	2.43	75.3% of 77	2.09

Math 30	85.2% of 27	2.82	93.3% of 30	2.65
Math 32	97.4% of 76	2.58	86.3% of 80	2.39

From Table 1, we see quite an interesting fact -- the average grade point is lower during the spring than fall for all courses, excluding Math 21 which had an anomalously low pass rate during the fall. This trend includes those courses having a higher pass rate in spring than fall.

Math 005: Preparatory Calculus

Figure 1. Spring 2008 Math 5 final grade distribution.



Of the 129 students enrolled in Math 5 during spring 2008, 43.4% (56) passed. Figure 1 above shows the grade distribution for the course. This pass rate is inconsistent from previous terms, which is described in Table 2. A similar pass rate can be seen during the fall 2005 term, but this was prior to the redevelopment of the pre-calculus curriculum. We attempt to explore reasons for this anomaly.

Table 2. Summary Math 5: Pre-Calculus enrollment and pass rates from fall 2005 to spring 2008.

Math 005: Preparatory Calculus		
Semester	Number Enrolled	Number Passing
Fall 2005	306	145 (47.4%)
Spring 2006	123	83 (67.5%)
Fall 2006	178	126 (70.8%)
Spring 2007	46	34 (73.9%)
Fall 2007	293	209 (71.33%)
Spring 2008	129	56 (43.4%)

Sections

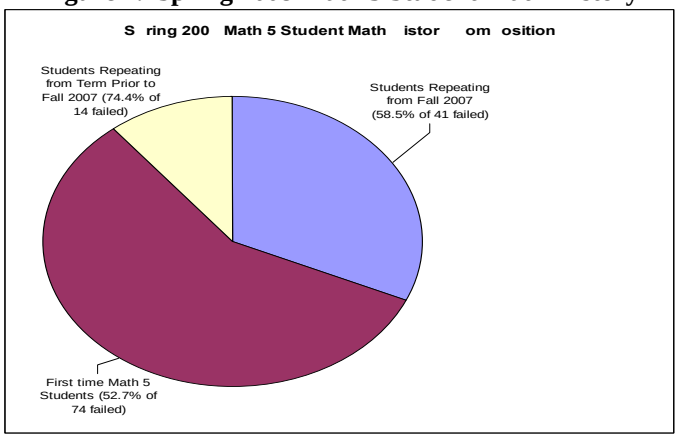
Viewing each section's enrollment numbers and the number of students passing, we hope to bring forth any problems within a particular section. There are five sections of Math 5 during spring 2008 and we have the following results.

- Section 1 (Bianchi) – 51.7% of the 29 enrolled passed.
- Section 4 (Bianchi) – 35.7% of the 28 enrolled passed.
- Section 6 (James) – 43.3% of the 30 enrolled passed.
- Section 7 (DaSilveira) – 40.7% of the 27 enrolled passed.
- Section 8 (James) – 46.7% of the 15 enrolled passed.

From the data, we see each section performed poorly. We conclude that there are no apparent issues with a specific Math 5 instructor.

Student Academic Math History
We begin by looking at the academic math history of students enrolled in Math 5 during the spring 2008 semester. Figure 3 describes the Math 5 course makeup.

Figure 2. Spring 2008 Math 5 Student Math History



From Figure 3, we notice more than 57% of students enrolled in Math 5 during the spring term were taking Math 5 for the first time, of which 39 (52.7%) did not pass the course. Of the 41 students repeating Math 5 from fall 2007, 24 (58.5%) did not pass the course and 10 of the 14 (74.4%) students repeating Math 5 from an earlier term did not pass. Thus, a large portion of the student population in this course had some time between their last math course and enrolling in Math 5. Numerous studies have shown that if mathematical concepts are not used, the ability to recall and utilize these techniques deteriorates. In addition, of the 73 students who failed Math 5, 57.5% (42) are in poor academic standing.

Gateway Exams
The gateway exam tests students in a variety of basic algebraic and computational skills needed throughout Math 5. The exam is administered within the first four weeks of classes and students are able to take the exam twice a day until the end of the four weeks. The results of spring 2008 semester's gateway exams are as follows.

- 80 students passed; 60% (48) passed Math 5.
- 33 students attempted, but did not pass; 15.2% (5) passed Math 5.
- 16 did not attempt; 18.8% (3) passed Math 5.

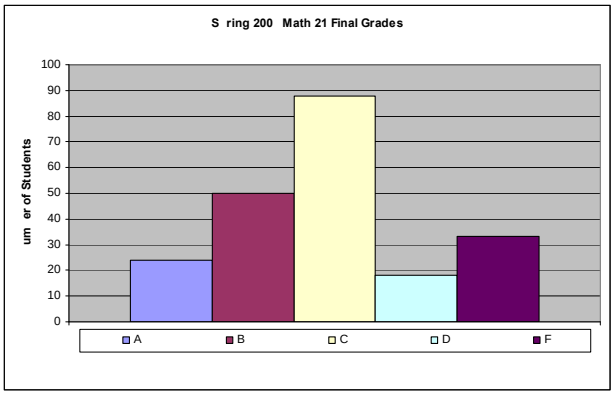
Similar to fall 2007's results, we see that by not passing the exam (attempt or no attempt) yields a substantially larger risk of failing the course – only 8 of 49 students who did not pass gateway managed to pass Math 5 during spring 2008 and 31 of 86 did so during fall 2007. This is somewhat to be expected since this implies two cases; either 1) a student attempted the gateway but lacks the necessary skills to pass the exam, thus lacking essential skills to be successful in pre-calculus or 2) did not attempt to take the gateway, demonstrating a lack of effort on the student's part.

Office Hours and Tutoring
Math 5 has benefited from having a group of instructors who have taught this course several times with adequate results (see Table 2 for each semester's data). One such instructor, Kristen Bianchi, has been teaching Math 5 since fall 2006. She states that

there has been minimal office hour attendance this term and Elizabeth Boretz, Director of the Student Advising and Learning Center, gives comparable data for tutorial sessions -- the same *nine* students attended. From this data, we infer students were not seeking the help needed.

Math 021: Calculus of a Single Variable

Figure 3. Spring 2007 Math 21 final grade distribution.



Of the 213 students enrolled, 76.1% (162) received a passing grade, which is a considerable increase from the fall 2007 pass rate of 55%. Figure 3, above, displays the Math 21 final grade distribution for the spring 2008 term.

Table 3. Summary Math 21: Calculus of a Single Variable enrollment and pass rates from Fall 2005 to spring 2008.

Math 021: Calculus of a Single Variable		
Semester	Number Enrolled	Number passing the course
Fall 2005	39	32 (82.1%)
Spring 2006	65	51 (78.5%)
Fall 2006	234	166 (70.9%)
Spring 2007	128	81 (63.3%)
Fall 2007	153	83 (55.0%)
Spring 2008	213	162 (76.1%)

From Table 3, we see the percentage of students passing Math 21 was steadily declining each term from fall 2005 until fall 2007, and drastically increased this term. At this point, it is unclear why this trend occurred.

Previous Math 5 Students

Previous Math 5 student performance in Math 21 is of interest as it helps us to assess how well our pre-calculus course is preparing students for further mathematics study. Of the 149 students who took Math 5 during fall 2007 and enrolled in Math 21 spring 2008, 80.5% (120) passed Math 21. The grade distribution is as follows.

- 17 received an A+, A, or A-
- 41 received a B+, B, or B-
- 62 received a C+, C, or C-
- 11 received a D+, D, or D-
- 18 received an F

Those students taking pre-calculus during fall 2007 at UC Merced appear to be well prepared for calculus. Table 3 below summarizes the number of students enrolled each term in Math 21, the number of students enrolling in Math 21 the term immediately following in Math 5, and the amount of those students who received a passing grade in Math 21 for each respective term.

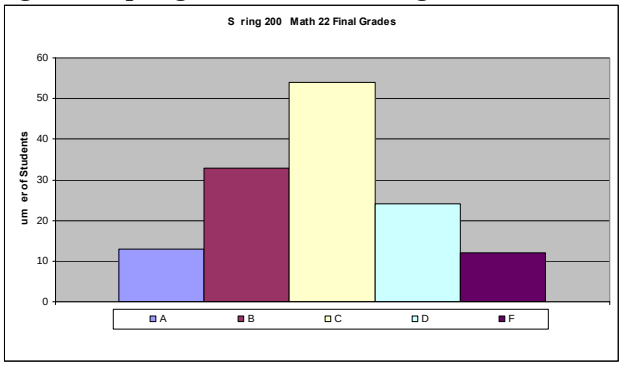
Table 4. Summary of previous Math 5 students' performance in Math 21 from spring 2006 to spring 2008.

Term	Total Enrolled in Math 21	Number enrolled from Math 5 previous semester	Number of Students Receiving an A, B, or C	
Spring 2006	65	47	38	80.90%
Fall 2006	234	54	26	48.10%
Spring 2007	128	72	44	61.10%
Fall 2007	151	11	3	27.30%
Spring 2008	214	149	120	80.50%

From Table 4, we see the fall term pass rate for students previously taking Math 5 at UC Merced are lowest during fall terms. This is somewhat to be expected since this is immediately following summer and the likelihood that students have used their pre-calculus skills during the summer months quite low. As suspected, students are most successful in calculus when taking it the semester immediately following Math 5.

<u>Math 022: Calculus of a Single Variable II</u>

Figure 4. Spring 2008 Math 22 final grade distribution.



Of the 136 students enrolled in Math 22, 73.5% (100) received a passing grade. Figure 4 shows the spring 2008 final grade distribution for Math 22. Table 5 below summarizes the enrollment numbers and pass rates for Math 22 from fall 2005 to spring 2008.

Table 5. Summary Math 22: Calculus of a Single Variable II enrollment and pass rates from fall 2005 to spring 2008.

Math 022: Calculus of a Single Variable II		
Semester	Number Enrolled	Number Passing
Fall 2005	19	18 (94.7%)
Spring 2006	76	68 (89.5%)
Fall 2006	113	69 (61.1%)
Spring 2007	139	54 (39.1%)
Fall 2007	121	93 (76.9%)
Spring 2008	136	100 (73.5%)

From Table 5, enrollment numbers appear to be leveling off at approximately 130 students per semester. The amount of students receiving a passing grade has been inconsistent. However, we have also had several instructors throughout the semesters. For the 2007 – 2008 academic year, Devin Greene has remained the instructor and we see similar pass rates for fall and spring terms.

Among those students enrolled in Math 22 during spring 2008,

- 43% took ICP 001 before Math 22
- 50.7% took Math 21 before Math 22

Among the 58 who took ICP 001,

- 2 received an A+, A, or A-
- 15 received a B+, B, or B-
- 20 received a C+, C, or C-
- 16 received a D+, D, or D-
- 5 received an F

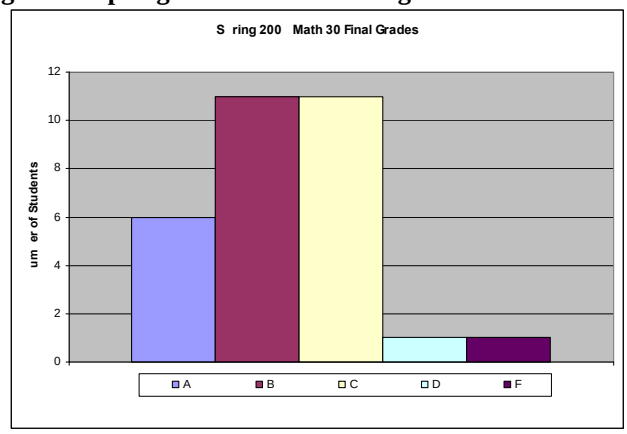
Among the 69 who took Math 21,

- 7 received an A+, A, or A-
- 18 received a B+, B, or B-
- 30 received a C+, C, or C-
- 8 received a D+, D, or D-
- 6 received an F

Thus, 36.2% of previous ICP 001 students failed Math 22 while 20% of previous Math 21 students failed Math 22.

<u>Math 030: Calculus of a Single Variable II for Biological Sciences</u>

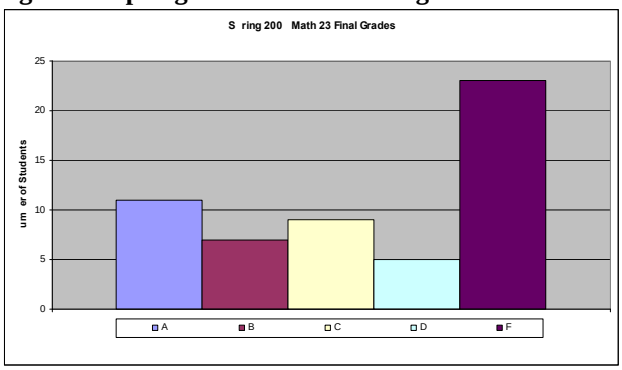
Figure 5. Spring 2008 Math 30 final grade distribution.



Of the 30 students enrolled in Math 30 during spring 2008, 93.3% (28) passed. Figure 5 shows the spring 2008 final grade distribution for the course. Since Math 30 is designed for the Biological Sciences majors, students taking Math 30 are not required to continue on in the mathematics course sequence and have not done so as of yet. Ideas for further assessment of this course are welcomed.

Math 023: Vector Calculus

Figure 6. Spring 2008 Math 23 final grade distribution.



Of the 56 students enrolled in Math 23 spring 2008, only 48.2% (27) received a passing grade. From Table 6, we notice that although there has not been a consistent pass/fail rate for Math 23, 48.2% is an abnormality.

Table 6. Summary Math 23: Vector Calculus enrollment and pass rates from fall 2005 to spring 2008.

Math 023: Vector Calculus		
Semester	Number Enrolled	Number Passing
Fall 2005	7	7 (100%)
Spring 2006	N/A	N/A
Fall 2006	45	27 (60.0%)
Spring 2007	56	45 (80.4%)
Fall 2007	56	37 (66.1%)
Spring 2008	56	27 (48.2%)

Students' Academic Math History

Among the 28 students that failed Math 23,

- 15 took Math 22 more than once
- 9 took Math 22 once, and are taking Math 23 for first time
- 2 are repeating Math 23 for second or third time
- 2 have no previous math history at UC Merced

Furthermore, among the 28 students who failed Math 23, 64.3% (18) are in "poor academic standing," meaning that they are having trouble in other courses as well as Math 23. A sufficient number of these students have a history of academic struggle.

Math 024: Linear Algebra and Differential Equations

Figure 7. Spring 2008 Math 24 final grade distribution.

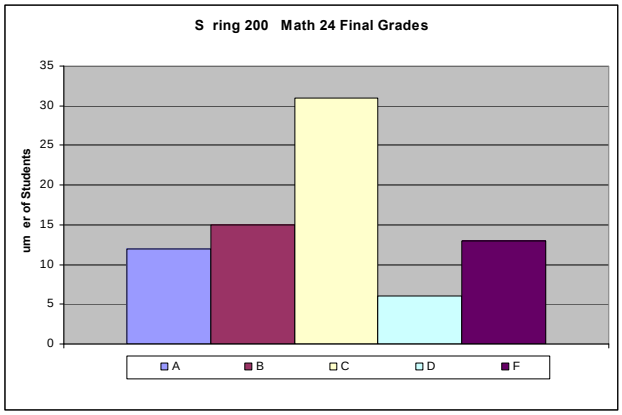


Figure 7 shows the spring 2008 Math 24 final grade distribution. Of the 77 students enrolled, 75.3% (58) received a passing grade. Table 7 gives the enrollment numbers and pass rates for Math 24 from fall 2005 to spring 2008.

Table 7. Summary Math 24: Linear Algebra and Differential Equations enrollment and pass rates from fall 2005 to spring 2008.

Math 023: Vector Calculus		
Semester	Number Enrolled	Number Passing
Fall 2005	N/A	N/A
Spring 2006	17	13 (76.5%)
Fall 2006	30	25 (83.3%)
Spring 2007	31	23 (74.2%)
Fall 2007	49	35 (71.4%)
Spring 2008	77	58 (75.3%)

Math 032: Probability and Statistics

Figure 8. Spring 2008 Math 32 final grade distribution.

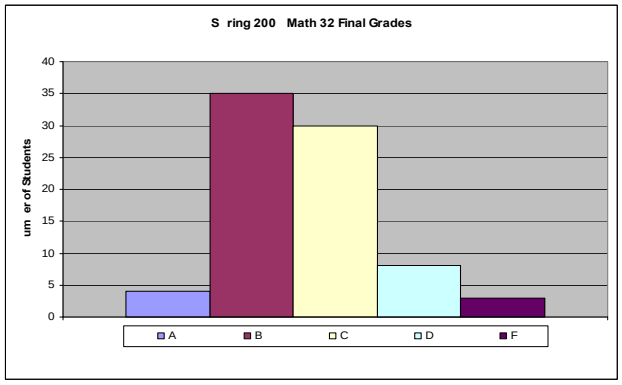


Figure 8 shows the spring 2008 Math 32 final grade distribution. Of the 80 students enrolled, 86.3% (69) received a passing grade.

Analyses of Fall 2008 Lower Division Mathematics Courses at UC Merced
Prepared by Cheryl Hedges
January 16, 2009

1.0 Pass/Fail rates by Course

What follows is an overview of lower division mathematics courses at UC Merced for the fall 2008 term. For the purposes of this document, a "C-" or better is considered "passing."

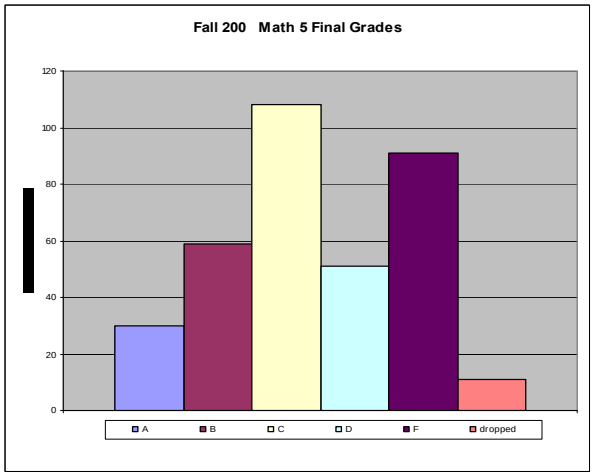
- Math 005 – 58.1% (197 of 339) of students passed
- Math 015 – 89.5% (51 of 57) of students passed
- Math 018 – 90.9% (40 of 44) of students passed
- Math 021 – 59.7% (178 of 298) of students passed
- Math 022 – 72.7% (112 of 152) of students passed
- Math 023 – 64.1% (50 of 78) of students passed
- Math 024 – 76.1% (54 of 71) of students passed
- Math 030 – 85.7% (30 of 35) of students passed
- Math 032 – 72.5% (50 of 69) of students passed

2.0 Course Data Analysis

Final grade distribution for each lower division mathematics course is described below. Additional data analysis follows to assist the UC Merced mathematics faculty in assessing lower division courses and student success.

2.1 Math 005: Pre-Calculus

Figure 1. Fall 2008 Math 5 final grade distribution.



2.1(a) Overview

Of the 339 students enrolled in Math 5 at the end of the fall 2008 semester, 58.1% (197) passed. At mid-semester, 51.3% of the 348 students were passing. Of those 348, 11 students dropped after mid-semester and 2 students enrolled from Math 21 into Math 5. Please refer to Figure 1 for the final grade distribution including those 11 students who dropped.

Table 1, below, shows each term's mid-semester and final pass rates for Math 5. Spring 2008 brought an anomalously poor pass rate, as did fall 2008. Although spring 2008 brought questions of apathetic student nature, the following of fall's pass rate brought forth the age-old question of student academic preparedness. This has been a topic of much discussion throughout the fall semester with the Math 5 instructors and math faculty. Two semesters of low pass rates is hardly a trend, but we explore various student assessment scores to help us gain a broader perspective of the student population and their incoming abilities.

Table 1. Math 5 mid-semester and final pass rates by term.

Term	Total Enrolled	Mid-semester	Final
Fall 2006	177	143 (80.8%)	126 (70.8%)
Spring 2007	46	38 (82.6%)	34 (73.9%)
Fall 2007	293	186 (62.8%)	209 (71.3%)
Spring 2008	129	82 (63.5%)	56 (43.4%)
Fall 2008	339	179 (51.3%)	197 (58.1%)

2.1(b) SAT Math Scores

Students enrolling at UC Merced are required to provide their SAT scores. The SAT Math score data can be broken up into two distinctive parts: those scoring above 500 and those scoring 500 or below. The fall 2008 student data is as follows:

- 154 students scored more than 500 on SAT Math; 76% (117) passed Math 5.
- 167 students scored 500 or less on SAT Math; 42.5% (71) passed Math 5.

Although SAT Math scores on their own cannot predict with accuracy a student's course readiness, it certainly gives us a mode to identify at an early stage potential students needing additional math preparation. We could recommend either a summer program or additional preparation at a community college level prior to fall enrollment.

2.1(c) Math Placement

The second tier of assessment is the math placement exam. Students entering UC Merced in fall 2008 took a math placement exam administered by Maple T.A. to assess their calculus readiness. This exam is a 25-question online, non-proctored exam. A student scoring 20 or more is recommended to enroll in Math 21, Calculus I, while those scoring 19 or less are recommended to take Math 5, Pre-Calculus, the university's only math course offered prior to Calculus I. This is the second year using a score of 20 as the cut-off into Math 21, but this is the third year using the Maple T.A. calculus readiness exam. Because of this, we are able to compare data from fall 2007 with data from 2008.

- During the fall 2008 semester, 75 students scored 10 or less on the math placement exam. *Only 23 of those 75 (30.7%) passed Math 5*. Additionally, 18 of the 23 who passed the course did so with a "C." Compare that number to the 203 students who scored 11 or more on the exam. Of those 203 students, 142 (70%) passed the course – a significant increase.

- Likewise, fall 2007 data shows students scoring 10 or less on the placement exam had an unfavorable pass rate – only 27 (52.9%) of 51 students passed Math 5. 80.7% (134) of the 166 students who scored 11 or more passed the course.

Conversely, viewing student performance for those hovering around the cut-off placement score of 20 yields the following for fall 2008:

- 85% (17) of 20 who scored 19 passed Math 5; 6 passed with a "C"
- 100% (15) of 15 who scored 18 passed Math 5; 9 passed with a "C"

Similarly, fall 2007 data shows the following:

- 80% (16) of 20 who scored 19 passed Math 5; 5 passed with a "C"
- 98.8% (23) of 24 who scored 18 passed Math 5; 6 passed with a "C"

This student population has done well in Math 5 for subsequent semesters. Perhaps we can entertain the idea of lowering the cut-off score for enrollment into Math 21. This would allow those students at the highest end of the spectrum in Math 5 to be challenged to a higher degree as well as narrow the range of preparedness in Math 5. Not only does this benefit the students, it allows instructors to better tailor their lectures to suit the majority of their student population.

The placement exam is proving to be a better predictor of success in Math 5 than SAT scores. Combining these two scores yields an even clearer result for fall 2008[*].

- A score of 510 or more on SAT Math
    - More than 10 on math placement; 14% (15) of 107 failed Math 5.
    - 10 or less on math placement; 47.4% (9) of 19 failed Math 5.
- A score of 500 or less on SAT Math
    - More than 10 on math placement; 37.9% (33) of 87 failed Math 5.
    - 10 or less on math placement; *77.4% (41) of 53 failed Math 5*.

Clearly, those students who scored 500 or less on SAT Math and 10 or less on placement are in need of additional support or even additional course preparation prior to Pre-calculus. Furthermore, all 12 students passing Math 5 in this category passed the course with a "C." Using these two exam scores, we can identify at an early stage those students who are considered "at-risk" in mathematics.

2.1(d) Gateway Exam

During Math 5, students take a gateway exam – an exam which tests students in a variety of basic algebraic and computational skills needed throughout Math 5. The exam is administered within the first four weeks of classes and students are able to take the exam twice a day until the end of the four weeks. Failing to pass the exam lowers the final grade by one-third of a letter grade. The results from fall 2008 are as follows:

[*] Students without SAT Math or placement scores are omitted from results.

- 230 students attempted and passed; 72.6% (167) passed Math 5.
- 94 students attempted the exam, but did not pass; 22.3% (21) passed Math 5.
- 26 did not attempt the exam; 34.6% (9) passed Math 5.

As seen below in Table 2, the odds of a student failing the gateway exam and passing the course are repeatedly low - only 22.3% (21) of the 94 students passed Math 5 this semester. It is important that instructors are given this data so they can clearly communicate the purpose of the gateway exam as well as the odds a student will pass the course if unable to pass the gateway exam. This gives students an opportunity to assess their level of preparedness and take action within the first few weeks of class.

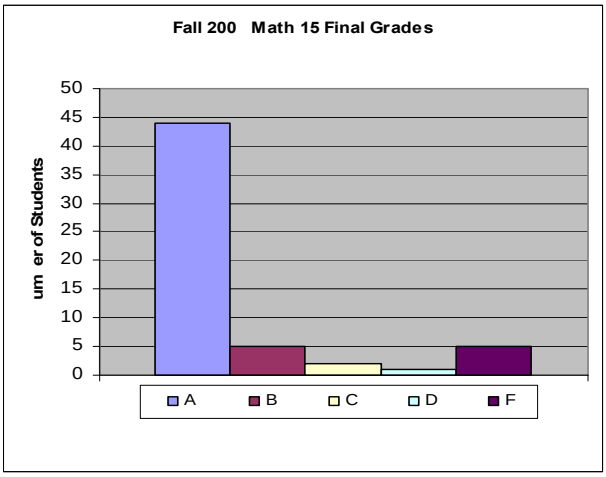
Table 2. Gateway Exam results and Pass rate by semester.

Semester	Passed Gateway	Passed Math 5	Failed Gateway	Passed Math 5
Fall 2007	217	179 (82.5%)	66	27 (40.9%)
Spring 2008	80	48 (60%)	33	5 (15.2%)
Fall 2008	230	167 (72.6%)	94	21 (22.3%)

Furthermore, one would assume students' placement exam score and gateway would be correlated, and indeed it is. During the fall 2008 semester, 46 students scored 10 or less on the placement and did not pass the gateway exam – 33 (71.7%) failed Math 5. The placement exam and gateway exam are two avenues students can assess their abilities within the first few weeks of the course.

2.2 Math 015: Intro to Scientific Data Analysis

Figure 2. Fall 2008 Math 15 final grade distribution.

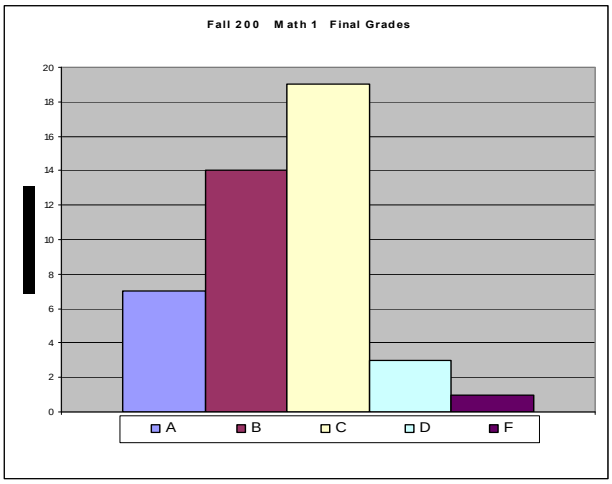


2.2(a) Overview

Of the 57 students enrolled in Math 15 at the end of fall 2008 semester, 89.5% (51) received a passing grade. As you will notice from Figure 2, the largest majority (44) students received an "A" which is consistent with previous semesters.

2.3 Math 018: Statistics for Scientific Data Analysis

Figure 3. Fall 2008 Math 18 final grade distribution.

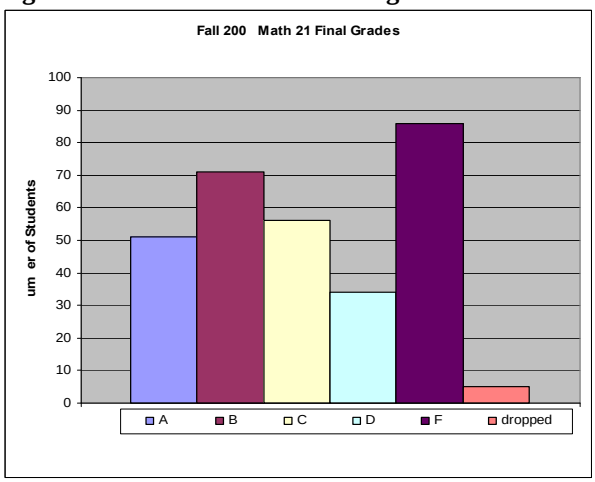


2.3(a) Overview

Of the 44 students enrolled in Math 18 at the end of the term, 90.9% (40) received a passing grade. Please refer to Figure 3 for the final grade distribution.

2.4 Math 021: Calculus of a Single Variable I

Figure 4. Fall 2008 Math 21 final grade distribution.



2.4(a) Overview

At mid-semester, 303 students were enrolled in Math 21 with 76.6% (232) of them passing. After mid-semester, 5 students dropped bringing the total number of enrolled students to 298. Of the 298 students enrolled in Math 21 at the end of the semester, 59.7% (178) received a passing grade. Refer to Figure 4 for the final grade distribution, including those 5 that dropped.

Table 3 shows the pass rates by semester for Math 21. As you can see, fall 2007 had a similar pass rate – 55% of the 153 enrolled. The past two fall semesters had large drops

in the number of people passing after mid-semester grades. We explore the student population to gain insight into this.

Table 3. Math 21 pass rate by semester.

Math 021: Calculus of a Single Variable		
Semester	um er Enrolled	um er assing the course
Fall 2005	39	32 (82.1%)
Spring 2006	65	51 (78.5%)
Fall 2006	234	166 (70.9%)
Spring 2007	128	81 (63.3%)
Fall 2007	153	83 (55.0%)
Spring 2008	213	162 (76.1%)
Fall 2008	298	178 (59.7%)

2.4(b) Student Population and Academic Background

Like that of previous years, the majority of students enrolled in Math 21 during the fall semester are freshmen. In fact, freshmen make up 77.5 % (231) of the 298 enrolled and 87.6% (156) of the 178 who passed. Freshmen make up 62.5% of those students who failed. The data for the remaining population is as follows:

- 62% (31) of the 50 students that took Math 5 at UCM failed Math 21.
    - 21 repeated Math 5 or Math 21; 17 (81%) failed Math 21.
    - 29 took Math 5 during the 2007-08 academic year; 14 (48.3%) failed Math 21.
- 14 students are either transfer or took Math 5 more than 1 year ago; 12 (85.7%) failed Math 21.

Last fall, similar numbers appeared pertaining to those who took Math 5 at UCM - 79.4% (27) of the 34 failed Math 21. However, at closer look, we see that many of those previous Math 5 students have a history of struggling in math courses as seen by the number of times they've repeated either Math 5 or Math 21. We see a similar result for the fall 2008 semester.

2.4(c) Math Placement

The largest population of students enrolled in Math 21 in fall 2008 is freshmen. Thus, it is appropriate to view the placement exam as we have shown in section 2.1(c), this has been a more accurate predictor of student success than SAT Math scores.

Figure 5. Fall 2008 math placement score vs. Math 21 final grade.

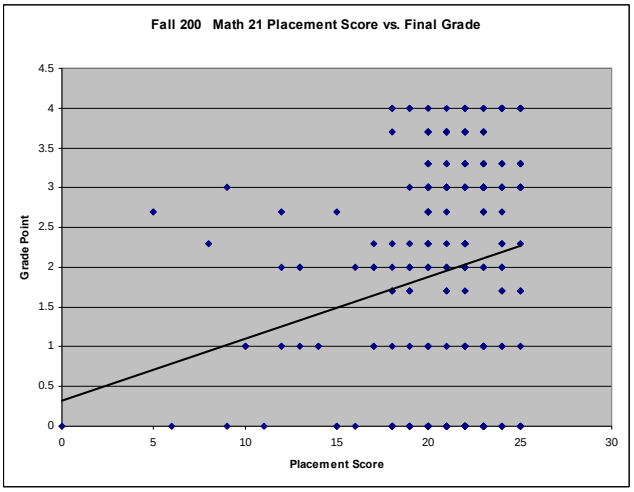


Figure 5, above, shows a weak, but positive correlation (R^2=0.0429). Table 4, below, describes the freshmen placement score for those students enrolled in Math 21 and the number passing the course. Those scoring below 20 faired the worst, along with those who scored 22 and 23. I'm not sure what this implies, if anything.

Table 4. Freshmen math placement score and pass rate for fall 2008.

Placement Score	Number of students	Number passing Math 21	
25	20	15	75.0%
24	26	21	80.8%
23	37	20	54.1%
22	41	22	53.7%
21	29	19	65.0%
20	33	22	66.7%
1	12	6	50.0%
1	10	5	50.0%
17	3	2	66.7%
1 or less	5	2	40.0%
o Score	20	15	75.0%

2.4(d) Class Time, Instructor, and T.A.

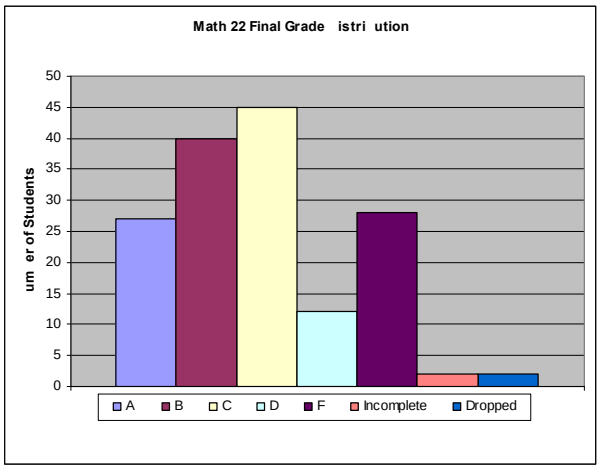
In hopes of gaining insight into reasons for a lower pass rate, I examined lecture and discussion times, lecturer, teaching assistant, and the number of freshmen enrolled by section. What I discovered was an inconsistency on all fronts. Some morning discussions did extremely well, while others did extremely poorly, which was the case for mid-day and evening courses as well. Each T.A. taught more than one section and had a range of outcomes in each section. Some sections with many freshmen preformed outstanding, while other sections with many freshmen did poorly. There appeared to be no recognizable pattern for any of these topics.

As stated earlier, two semesters is not a trend, but the question remains, what happened post mid-semester? Perhaps freshmen get too comfortable, or become overwhelmed or

lazy; however, under further examination on 36 of the 65 students who were performing well at mid-semester and failed at the end of the term were freshmen. Compared to the number of freshmen enrolled in this course, this is not a significant number. Thus, the majority of students whose grade decreased considerably were everyone but freshmen students.

2.5 Math 022: Calculus of a Single Variable II

Figure 6. Fall 2008 Math 22 final grade distribution.



2.5(a) Overview

At mid-semester, 156 students were enrolled in Math 22 with 78.2% (122) of them passing. After mid-semester, 2 students dropped and 2 students have finished the semester with an "incomplete." Of the 154 students enrolled at the end of the semester, 72.7% (112) have received a passing grade. Refer to Figure 6 for final grade distribution.

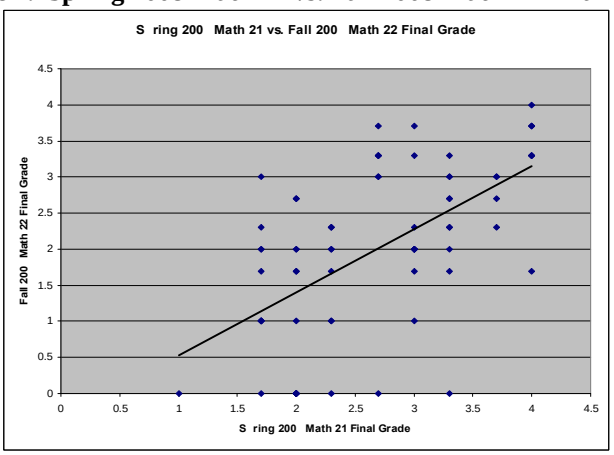
The majority of the Math 22 population is comprised of transfer students and those that took Calculus I at UCM during the spring 2008 term. These two groups of populations make up 72.7% (112) of the 154 enrolled. The academic background for those data is as follows:

- 71.8% (51) of 71 spring 2008 Math 21 students passed Math 22.
- 87.8% (36) of 41 transfer students passed Math 22.
- 46.7% (7) of 15 students repeating Math 22 from spring '08 passed.
- 66.7% (18) of 27 students who took Math 21 before spring 2008 or took Calculus I at other college/university passed Math 22 at UCM.

Transfer students make up 26.6% of the total enrolled and comprise 32.1% of those that passed. UCM students who took Math 21 during spring 08 are 46.1% of the total enrolled and compose 45.5% of those who passed.

Figure 7 below shows the correlation between spring '08 Math 21 grades and fall '08 Math 22 final grades. A positive correlation ($R^2 = 0.3433$) is found, which is stronger than spring 2008's correlation ($R^2=0.1289$).

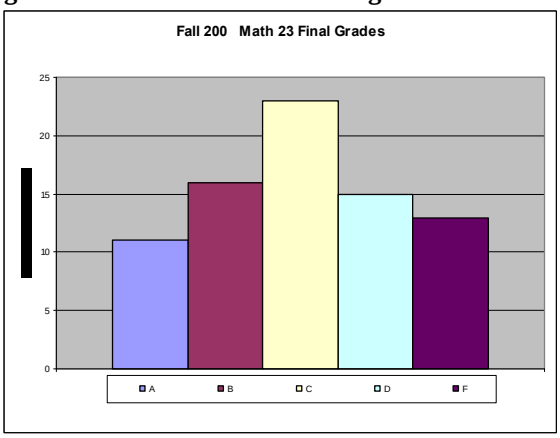
Figure 7. Spring 2008 Math 21 vs. Fall 2008 Math 22 Final Grade



There are 58 students "on track." In other words, they took Math 5 during fall 2007, Math 21 during spring 2008, and Math 22 fall 2008. Of those 58, 43 (74.1%) passed Math 22. These are positive numbers. Thus, 74.1% of the 58 students who entered UCM with a weak background in math (i.e. are not placed into Math 21 during freshmen year), are performing sufficiently well in Math 22. This implied that if students make it through Math 5 and Math 21, they are adequately prepared for Math 22.

2.6 Math 023: Vector Calculus

Figure 8. Fall 2008 Math 23 final grade distribution.



2.6(a) Overview

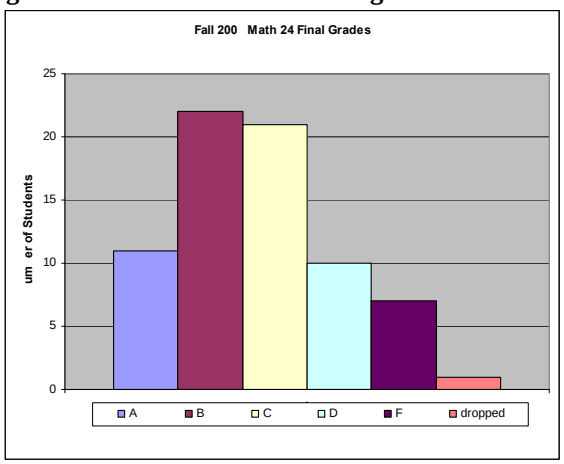
Of the 78 students enrolled in Math 23 during the fall 2008 semester, 64.1% (50) received a passing grade. Refer to Figure 8 for the final grade distribution.

Most students enrolled in Math 23 took Math 22 here at UCM. The student population math background and pass rates are as follows:

- 35 took Math 22 during spring 2008 term; 25 (71.4%) passed Math 23.
- 21 took Math 22 during fall 2007 term; 14 (66.7%) passed Math 23.
- 14 students are repeating Math 23 from the 2007 – 2008 academic year; 8 (57.1%) passed.
- 8 students have no previous math history at UCM; 3 (37.5%) passed.

2.7 Math 024: Linear Algebra and Differential Equations

Figure 9. Fall 2008 Math 24 final grade distribution.



2.7(a) Overview

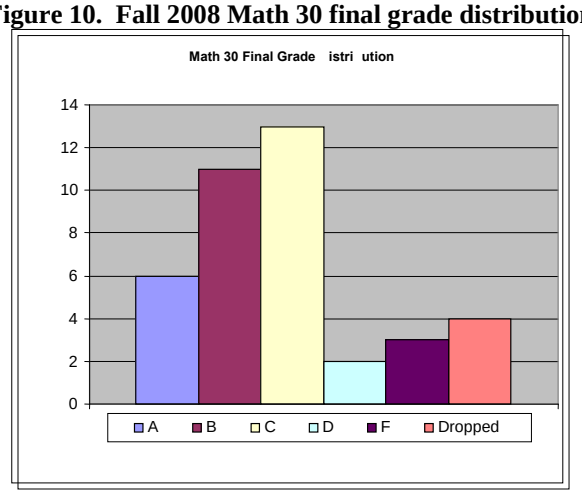
At mid-semester, 73.6% (53) of the 72 students enrolled in Math 24 were passing. At the end of the fall 2008, 71 students remained with 76.1% (54) receiving a passing grade for the course. Refer to Figure 9 to view the final grade distribution.

Math 24's prerequisite is Math 22 and can be taken concurrently with Math 23. However, most students choose to take Math 23 immediately following Math 22 and then enroll in Math 24. At present, the order appears to have no bearing on student success. The number of transfer students passing was the lowest out of all student math backgrounds, however, not enough to be of concern. The data for students enrolled during fall 2008 is as follows:

- 10 students took Math 22 spring 2008; 7 (70%) passed Math 24.
- 7 took Math 23 and Math 24 concurrently during fall 2008; 6 (85.7%) passed Math 24.
- 27 took Math 23 in spring 2008; 24 (88.9%) passed Math 24.
- 15 new transfer students; 10 (66.7%) passed Math 24.
- 12 students who transferred to UCM during a previous term; 7 (58.3%) passed Math 24.

2.8 Math 030: Calculus II for Biological Sciences

Figure 10. Fall 2008 Math 30 final grade distribution.

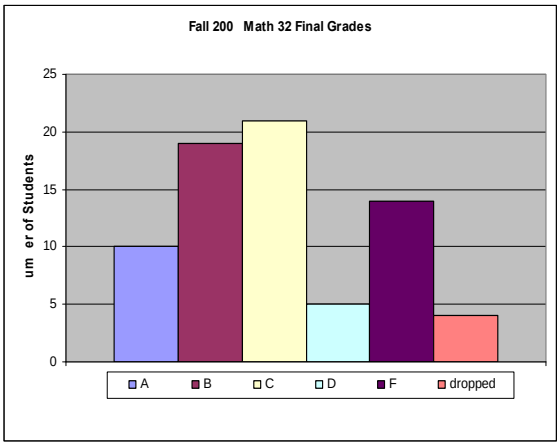


2.8(a) Overview

At mid-semester, 59% (23) of the 39 enrolled students were passing. At the end of the fall 2008 semester, 85.7% (30) of the 35 who remained enrolled in Math 30 passed the course. Refer to Figure 10 to view the final grade distribution, including those 4 students who dropped.

2.9 Math 032: Probability and Statistics

Figure 11. Fall 2008 Math 32 final grade distribution.



2.9(a) Overview

At mid-semester, 54.8% (40) of the 73 enrolled students were passing. After mid-semester, 4 students dropped bringing the total to 69 of which 72.5% (50) passed the course. Refer to Figure 11 for the final grade distribution, including those 4 students who dropped.

Analyses of Fall 2009 Lower Division Mathematics Courses at UC Merced

Prepared by Alice Moua and Masa Watanabe

January 20, 2010

1.0 Pass/Fail rates by Course

What follows is an overview of lower division mathematics courses at UC Merced for the fall 2009 term. For the purposes of this document, a "C-" or better is considered "passing."

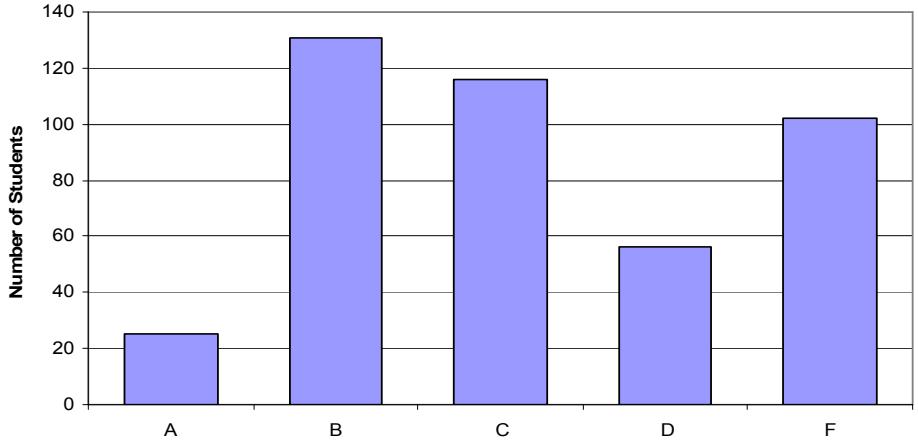
- **Math 005 – 63.3% (272 of 430) of students passed**
- Math 015 – 94.1% (158 of 168) of students passed
- **Math 021 – 63.9% (200 of 313) of students passed**
- Math 022 – 80.5% (132 of 164) of students passed
- Math 023 – 82.2% (106 of 129) of students passed
- Math 024 – 83.5% (66 of 79) of students passed
- Math 030 – 73.5% (25 of 34) of students passed
- Math 032 – 85.1% (57 of 67) of students passed

2.0 Course Data Analysis

Final grade distribution for each lower division mathematics course is described below. Additional data analysis follows to assist the UC Merced mathematics faculty in assessing lower division courses and student success.

2.1 Math 005: Pre-Calculus

Figure 1. Fall 2008 Math 5 final grade distribution.



2.1(a) Overview

Of the 430 students enrolled in Math 5 at the end of the fall 2009 semester, 63.3% (272) passed. At mid-semester, 74.4% of the 434 students were passing. Of those 434, 3 students dropped after mid-semester and 1 student got an "incomplete". Please refer to Figure 1 for the final grade distribution excluding those 4 students.

Table 1, below, shows each term's mid-semester and final pass rates for Math 5. Although Fall 2009 had a highest pass rate among recent years, the pass rate of 63.3% for pre-calculus course certainly brought forth a question of student academic preparedness. We explore various student assessment scores to help us gain a broader perspective of the student population and their incoming abilities.

Table 1. Math 5 mid-semester and final pass rates by term.

Fall	Total	Midterm*	Final	Spring	Total	Midterm*	Final
2006	177	143 (80.8%)	126 (70.8%)	2007	46	38 (82.6%)	34 (73.9%)
2007	293	186 (62.8%)	209 (71.3%)	2008	129	82 (63.5%)	56 (43.4%)
2008	350	179 (51.3%)	197 (56.3%)	2009	175	113 (63.5%)	100 (57.1%)
2009	430	323 (74.4%)	272 (63.3%)				

*In general, total number of Math 5 students prior to Midterm report is slight higher than total number reported here. Numbers of students tends to withdraw the class after having a Midterm grade report.

2.1(b) SAT Math Scores

Students enrolling at UC Merced are required to provide their SAT scores. The SAT Math score data can be broken up into two distinctive parts: those scoring above 500 and those scoring 500 or below. Of the 430 students enrolled in Math 5 at the end of the fall 2009 semester, 320 students are freshmen. The fall 2009 freshman student data is as follows:

- 143 freshman students scored more than 500 on SAT Math; 84% (120) passed Math 5.
- 162 freshman students scored 500 or less on SAT Math; 51% (83) passed Math 5.
- 15 freshman students had no SAT score; 40% (6) passed Math 5.

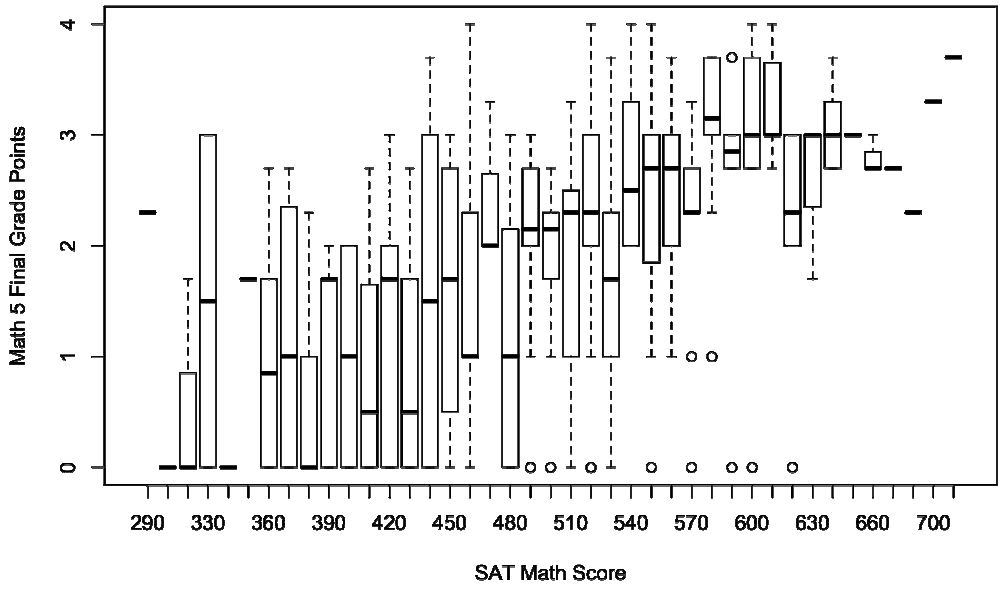


Figure 2 Fall 2009 math SAT score vs. Math 5 final grade. This graph represents its (25% and 75%) quartiles, as well as minimum and maximum values. The bold line indicates a median of each data set.

According to Figure 2, SAT Math Score is correlated with Math 5 Final Grade.(ANOVA shows *p-value* $< 10^{-6}$). SAT Math scores certainly give us a mode to identify at an early stage potential students needing additional math preparation. We could recommend either a summer program or additional preparation at a community college level or summer bridge program prior to fall enrollment.

2.1(c) Math Placement

The second tier of assessment is the math placement exam. Students entering UC Merced in fall 2009 took a math placement exam to assess their calculus readiness. This exam is a 25-question

online, non-proctored exam. A student scoring 20 or more is recommended to enroll in Math 21, Calculus I, while those scoring 19 or less are recommended to take Math 5, Pre-Calculus, the university's only math course offered prior to Calculus I.

- During the fall 2009 semester, 88 students who scored 10 or less on the math placement exam took Math 5. *Only 32 of those 88 (36.4%) passed Math 5*. Additionally, 19 of the 32 who passed the course did so with a "C." Compare that number to the 253 students who scored 11 or more on the exam and took Math 5. Of those 253 students, 183 (72.3%) passed the course – a significant increase. Figure 3 shows that Placement scores is also correlated with Math 5 Final Grade. (ANOVA shows *p-value* $< 10^{-6}$).

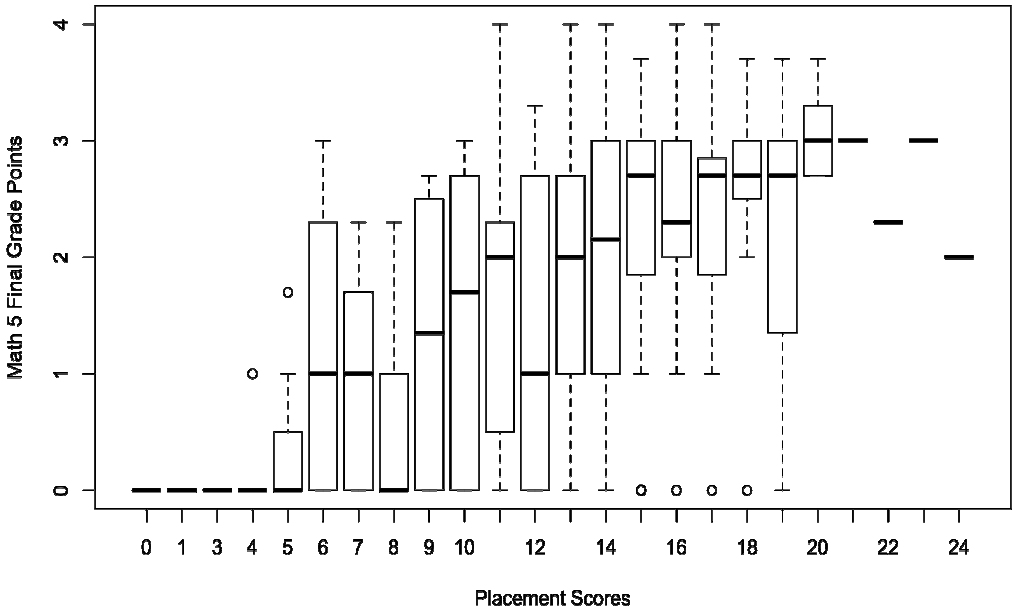


Figure 3 Fall 2009 math placement score vs. Math 5 final grade. The bold line indicates a median of each data set.

- Likewise, fall 2007 and fall 2008 data show that students scoring 10 or less on the placement exam had an unfavorable pass rate. Also we have been observing a significant increase in a pass rate for students who scored 11 or more on the placement.

Conversely, viewing student performance for those hovering around the cut-off placement score of 20 yields the following for fall 2009:

- 75.0% (18) of 24 who scored 19 passed Math 5; 5 passed with a "C"
- 95.7% (22) of 23 who scored 18 passed Math 5; 5 passed with a "C"

Similarly,
Fall 2007 data shows the following:

- 80% (16) of 20 who scored 19 passed Math 5; 5 passed with a "C"
- 98.8% (23) of 24 who scored 18 passed Math 5; 6 passed with a "C"

Fall 2008 data shows the following:

- 85% (17) of 20 who scored 19 passed Math 5; 6 passed with a "C"
- 100% (15) of 15 who scored 18 passed Math 5; 9 passed with a "C"

The placement exam is proving to be a better predictor of success in Math 5 than SAT scores. Combining these two scores yields an even clearer result for fall 2009*.

- A score of 510 or more on SAT Math
  - More than 10 on math placement; 12.6% (14) of 111 freshmen failed Math 5.
  - 10 or less on math placement; 63.6% (7) of 11 freshmen failed Math 5.
- A score of 500 or less on SAT Math
  - More than 10 on math placement; 37.6% (38) of 101 freshmen failed Math 5.
  - 10 or less on math placement; 63.6% (28) of 44 freshmen failed Math 5.

Clearly, those freshman students who scored 500 or less on SAT Math and 10 or less on placement are in need of additional support or even additional course preparation prior to Pre-calculus. Furthermore, all 12 students passing Math 5 in this category passed the course with a "C." Using these two exam scores, we can identify at an early stage those students who are considered "at-risk" in mathematics.

2.1(d) Retake

Table 2 indicates that pass rates for students who retook Math 5 are much lower than one for those who took Math 5 first time.

Table 2. # of retakes and their results

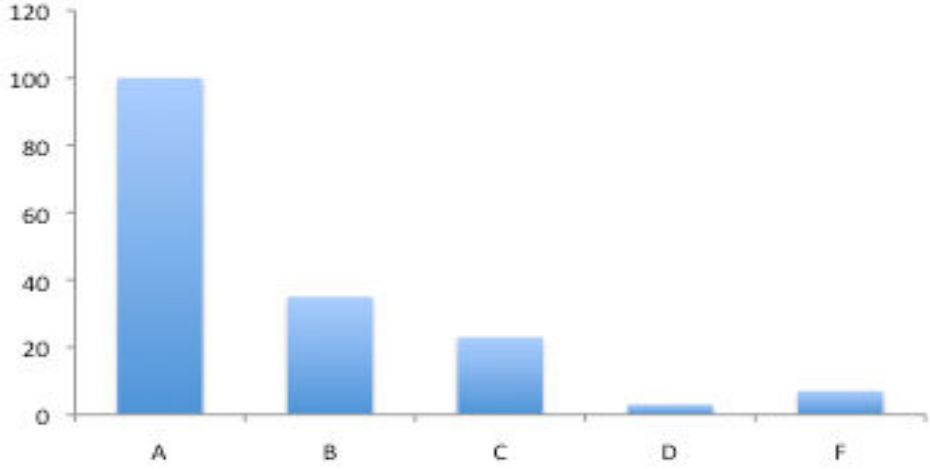
# of Retake	# of Students	Passed Math 5	Failed Math 5
0	342	234 (68.4%)	108 (31.6%)
1	80	34 (42.5%)	46 (57.5%)
2	8	4 (50.0%)	4 (50.0%)

Suggestion: Perhaps we can revisit a rubric to set the cut-off score for enrollment into Math 21. One suggestion of the cut-off is that 1) SAT Math score (> 500) with 10 or more placement score or 2) SAT Math score (<= 500) with 19 or more placement score. If any students meet one of these criteria, those should be recommended to take Math 21. Not only does this benefit the students, it allows instructors to better tailor their lectures to suit the majority of their student population.

* Students without SAT Math or placement scores are omitted from results.

2.2 Math 015: Intro to Scientific Data Analysis

Figure 4. Fall 2009 Math 15 final grade distribution.

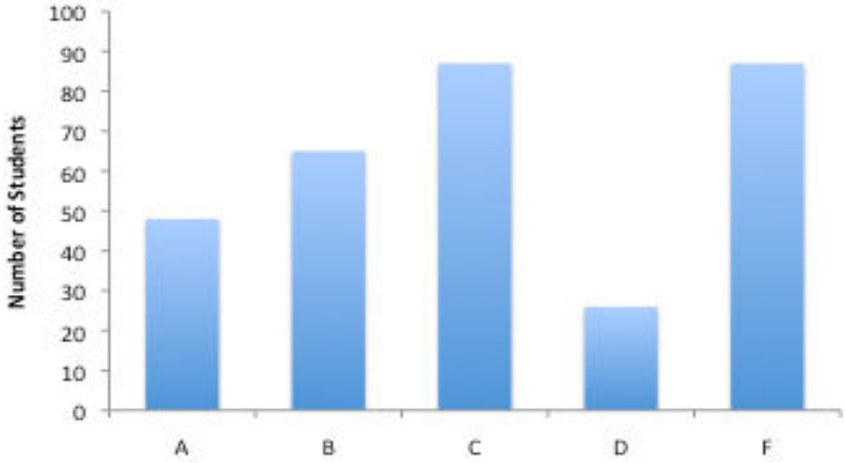


2.2(a) Overview

Of the 169 students enrolled in Math 15 at the end of fall 2009 semester, 94.0% (158) received a passing grade. As you will notice from Figure 4, the largest majority students received an "A-" or better which is consistent with previous semesters.

2.3 Math 021: Calculus of a Single Variable I

Figure 5. Fall 2009 Math 21 final grade distribution.



2.4(a) Overview

At mid-semester, 317 students were enrolled in Math 21 with 74.4% (236) of them passing. After mid-semester, 3 students dropped and 1 student got "incomplete". That brought the total number of enrolled students to 313. Of the 313 students enrolled in Math 21 at the end of the semester, 63.9% (200) received a passing grade. Refer to Figure 5 for the final grade distribution.

Table 3 shows the pass rates by semester for Math 21. As you can see, fall 2009 had a better pass rate than those of the past two fall semesters. Also, we explore the student population to gain more insight into student preparedness and readiness.

Table 3. Math 21 pass rate by semester.

Math 021: Calculus of a Single Variable		
Semester	**Number Enrolled**	**Number passing the course**
Fall 2005	39	32 (82.1%)
Spring 2006	65	51 (78.5%)
Fall 2006	234	166 (70.9%)
Spring 2007	128	81 (63.3%)
Fall 2007	153	83 (55.0%)
Spring 2008	213	162 (76.1%)
Fall 2008	298	178 (59.7%)
Spring 2009	266	154 (57.9%)
Fall 2009	313	200 (63.9%)

2.4(b) Student Population and Academic Background

This semester, 49.2% (154) of students enrolled in Math 21 during the fall semester are freshmen, who had never taken any Math courses at UC Merced before. This number was much smaller than previous three years: in fall 2008, freshmen make up 77.5 %. 76.6% (118) of those 154 freshman students passed. Freshmen make up 31.9% of those students who failed.

This semester, number of sophomore students (132) and twenty-three freshmen, who took Math 5 at UC Merced before, enrolled in Math 21 was increased to 42.2%. The data for the remaining population is as follows:

- 63.4% (69) of the 108 students that took Math 5 at UCM failed Math 21.
    - 57 of those 108 students got Math 5 grade "C+" or lower. Of those 57 students, 42 (75.4%) failed Math 21

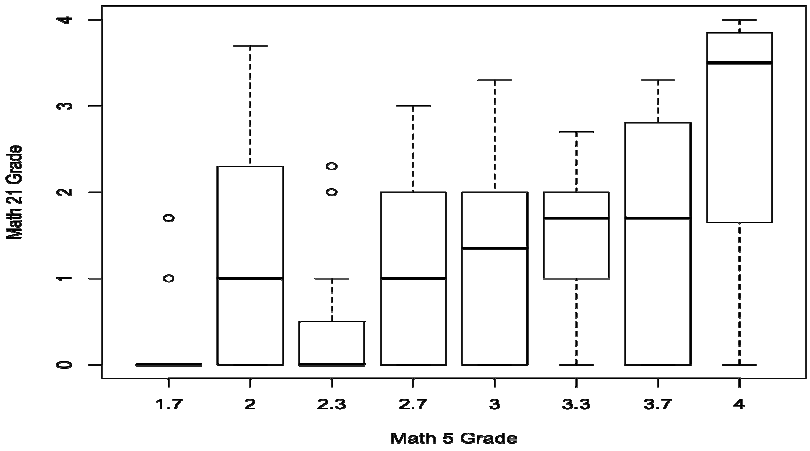


Figure 6 Fall 2009 Math 5 final grade vs Math 21 final grade for students who took Math 5 at UCM. The bold line indicates a median of each data set. The analysis shows *p-value* = 0.001935

- 30 repeated Math 5; 25 (83.3%) failed Math 21.
  - 22 of 108 repeated Math 5 twice
  - 8 of 108 repeated Math 5 three times

- 52 students are either transfer or took pre-calculus at another college; 8 (15.4%) failed Math 21.

We have seen that many of those previous Math 5 students have a history of struggling in math courses as seen by the number of times they've repeated either Math 5 or Math 21. We see a similar result for other semesters.

2.4(c) Math Placement

Among 177 freshmen of students enrolled in Math 21 in fall 2009, it is appropriate to view the placement exam as we have shown in section 2.1(c).

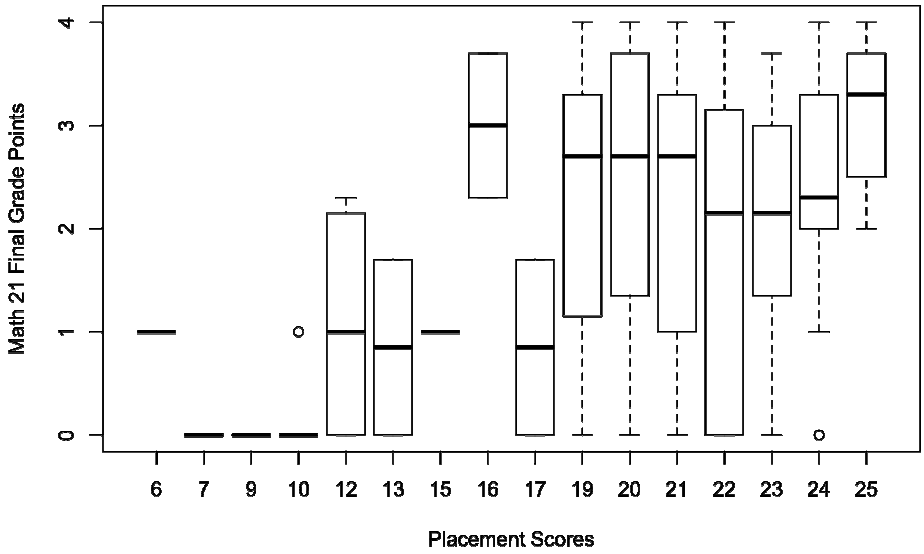


Figure 7 Fall 2009 math placement score vs. Math 21 final grade for freshman students. The bold line indicates a median of each data set.

Figure 7, above, shows that placement scores are also correlated with Math 21 Final Grades. Table 4, below, describes the freshmen placement score for those students enrolled in Math 21 and the number passing the course. Those scoring below 19 faired the worst. Both Figure 7 and Table 4 strongly support that the scoring rubric for 19 if SAT Math scores are not counted.

Table 4. Freshmen math placement score and pass rate for fall 2009.

Placement Score	Number of students	Number passing Math 21	
25	11	11	100.0%
24	21	18	85.8%
23	20	15	75.0%
22	20	13	65.0%
21	29	21	72.4%
20	35	26	74.3%
19	11	8	72.7%
18	0	–	–
17	4	2	50.0%
16 or less	17	5	29.4%
No Score	10	7	70.0%

2.4(d) Math 21 Retake

Table 5 indicates that pass rates for students who retook Math 21 are much lower than one for those who took Math 21 for the first time.

Table 5. Fall 2009 - number of retakes and their results

# of Retake	# of Students	Passed Math 21	Failed Math 21
0	278	180 (64.7%)	98 (35.3%)
1	32	18 (56.2%)	14 (43.8%)
2	2	2 (100%)	0 (0.0%)
3	1	0 (0.0%)	1 (100%)

Suggestion: Based on the observation, we may need to consider reviewing a prerequisite for Math 21. Maybe we should impose that student must pass Math 5 with a grade of "C" or better in order to take Math 21.

2.5 Math 022: Calculus of a Single Variable II

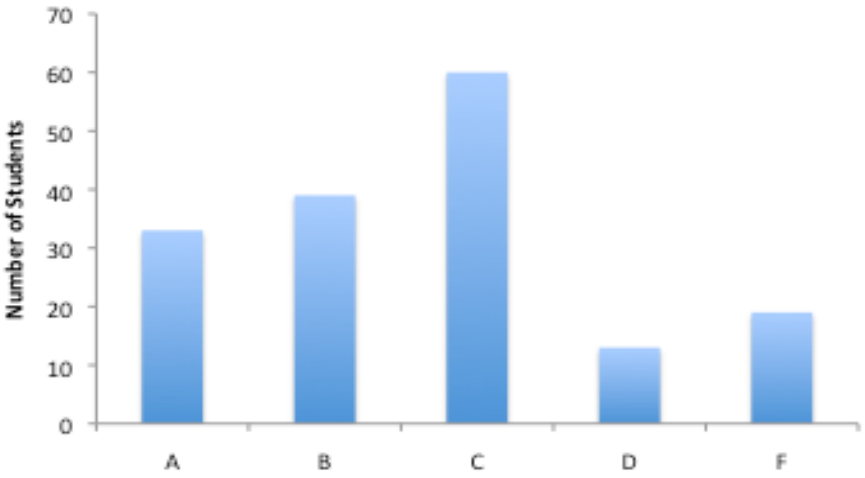


Figure 8 Fall 2009 Math 22 final grade distribution.

2.5(a) Overview

At mid-semester, 166 students were enrolled in Math 22 with 67.5% (112) of them passing. After mid-semester, 2 students dropped. Of the 164 students enrolled at the end of the semester, 80.5% (132) have received a passing grade. Refer to Figure 8 for final grade distribution.

The majority of the Math 22 population is those that took Calculus I at UCM before. These two groups of populations make up 68.9% (113) of the 164 enrolled. Transfer students make up 17.1% of the total enrolled. The academic background for those data is as follows:

- 96.4% (109) of 113 students who took Math 21 at UCM passed Math 22.
    - 97.6% (82) of 84 students who took Math 21 once at UCM passed Math 22.
    - 96.0% (24) of 25 students who took Math 21 twice at UCM passed Math 22.
- 89.2% (25) of 28 transfer students passed Math 22.
- 95.7% (22) of 23 freshmen, who took Calculus I at other college/university or pass AP test, passed Math 22.

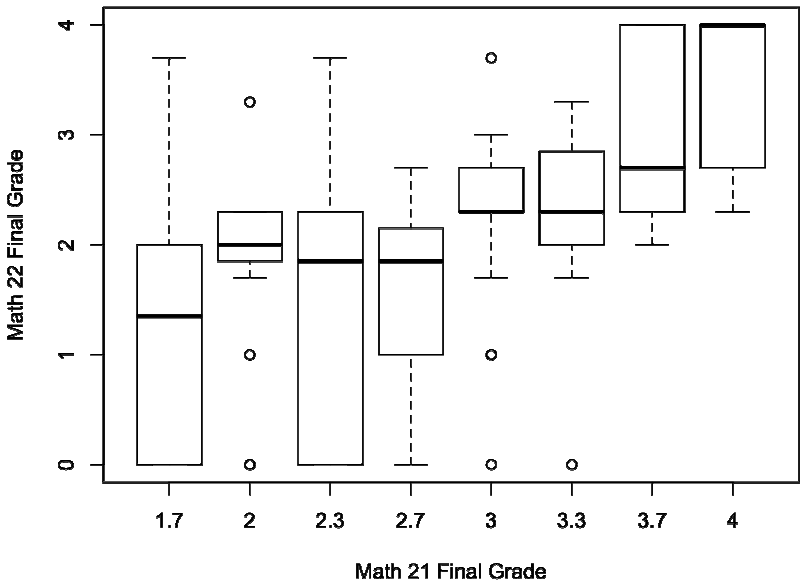


Figure 9 Fall 2009 Math 21 final grade vs. Math 22 final grade for students who took Math 21 at UCM . The bold line indicates a median of each data set. ANOVA indicates p-value is less than 10^{-8}.

Figure 9 below shows the correlation between Math 21 grades and Math 22 final grades. Also, our analysis suggest that if students make Math 22 through Math 21 at UCM, they are adequately prepared for Math 22.

2.6 Math 023: Vector Calculus

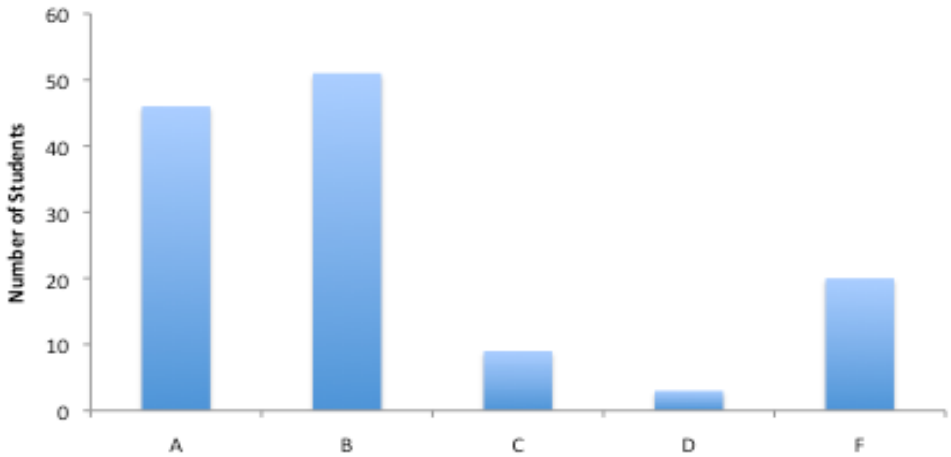


Figure 10. Fall 2009 Math 23 final grade distribution.

2.6(a) Overview

At mid-semester, 136 students were enrolled in Math 23 with 72.8% (99) of them passing. After mid-semester, 7 students dropped. Of the 129 students enrolled at the end of the semester, 82.2% (106) have received a passing grade. Refer to Figure 10 for final grade distribution.

Most students enrolled in Math 23 took Math 22 here at UCM. The student population math background and pass rates are as follows:

- 98 students who passed Math 22 at UCM; 85 (86.7%) passed Math 23.
- 16 students are repeating Math 23 from previous academic years;
    - 83.3% (10) of 12 students who repeated once at UCM passed.
    - 100% (4) of 4 students who repeated twice or more at UCM passed.
- 67.7% (21) of 31 students, who took Calculus II at other college/university or pass AP Calculus BC test, passed Math 23.

2.7 Math 024: Linear Algebra and Differential Equations

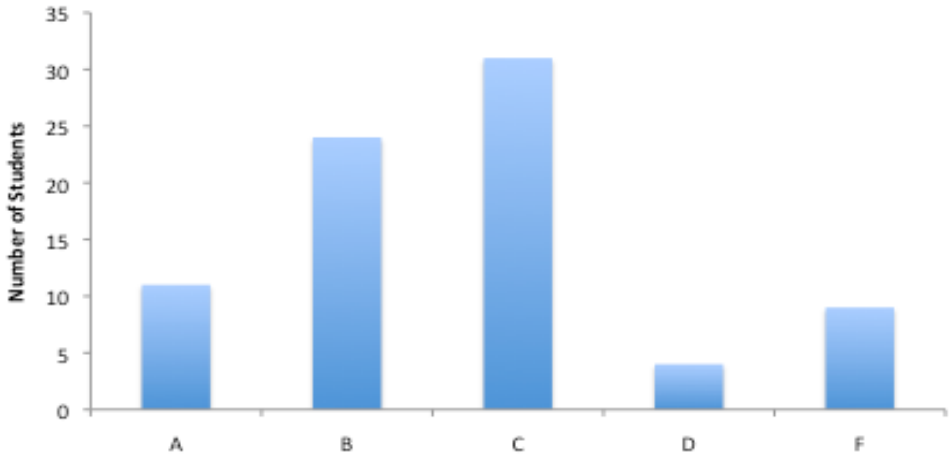


Figure 11. Fall 2009 Math 24 final grade distribution.

2.7(a) Overview

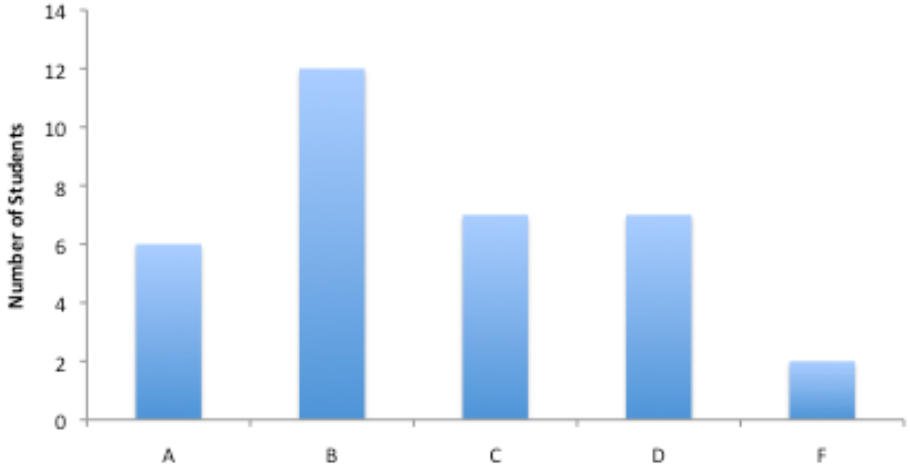
At mid-semester, 74.1% (60) of the 81 students enrolled in Math 24 were passing. At the end of the fall 2009, 79 students remained with 83.5% (66) receiving a passing grade for the course. Refer to Figure 11 to view the final grade distribution.

Math 24's prerequisite is Math 22 and can be taken concurrently with Math 23. However, most students choose to take Math 23 immediately following Math 22 and then enroll in Math 24. The data for students enrolled during fall 2009 is as follows:

- 46 students who previously passed Math 22 at UCM; 42 (91.3%) passed Math 24.
    - Of those 46, nine students are repeating Math 24 from previous academic years;
        - 71.4% (5) of 7 students who repeated once at UCM passed.
        - 50.0% (1) of 2 students who repeated twice at UCM passed.
- 69.7% (23) of 33 students, who took Vector Calculus at other college/university, passed Math 24.
- 15 took both Math 23 and Math 24 concurrently during fall 2009; 11 (73.3%) passed Math 24.
    - Of those 11, 10 students passed Math 23

2.8 Math 030: Calculus II for Biological Sciences

Figure 12. Fall 2009 Math 30 final grade distribution.



2.8(a) Overview

At mid-semester, 85.7% (30) of the 35 enrolled students were passing. At the end of the fall 2009 semester, 73.5% (25) of the 35 who remained enrolled in Math 30 passed the course. Refer to Figure 12 to view the final grade distribution, excluding 1 student who dropped.

2.9 Math 032: Probability and Statistics

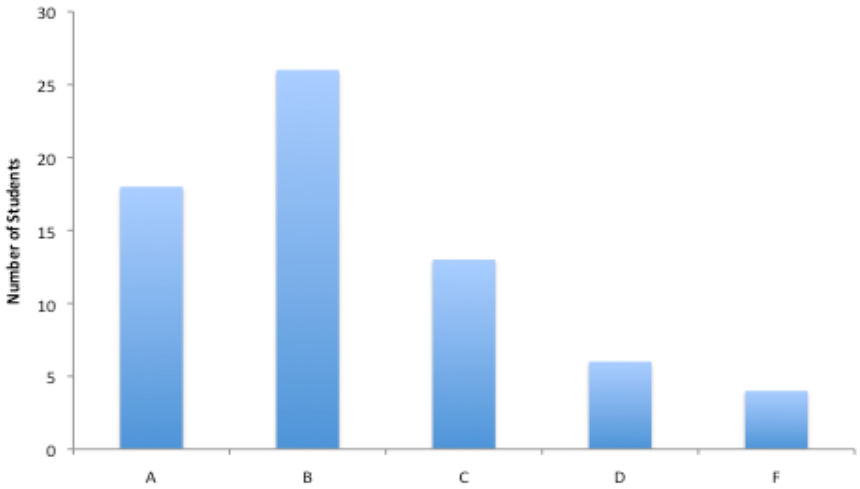


Figure 13 Fall 2009 Math 32 final grade distribution.

2.9(a) Overview

At mid-semester, 59.7% (40) of the 72 enrolled students were passing. After mid-semester, 5 students dropped bringing the total to 67 of which 85.1% (57) passed the course. Refer to Figure 13 for the final grade distribution, excluding those 5 students who dropped.

Spring 2009 Lower Division Mathematics Course Summary
Prepared by Cheryl Hedges
June 26, 2009

Spring 2009 Semester Course Overview

What follows is a brief overview of mathematics courses during the spring 2009 term. For the purpose of this document, a letter grade of "C-" or higher is considered "passing."

- Math 005 – 57.1% (100 of 175) passed
- Math 015 – 94.9% (37 of 39) passed
- Math 018 – 83.8% (31 of 37) passed
- Math 021 – 57.9% (154 of 266) passed
- Math 022 – 76.0% (133 of 175) passed
- Math 023 – 69.2% (63 of 91) passed
- Math 024 – 75.9% (63 of 83) passed
- Math 030 – 90.9% (20 of 22) passed
- Math 032 – 60.0% (45 of 79) passed

Math 005: Preparatory Calculus

Of the 175 students enrolled at the end of spring 2009, 57.1% (100) passed. At mid-semester 63.5% (113) of the 178 students were passing, and 3 students dropped after mid-semester grades. Please refer to Figure 1 for the final grade distribution, including those students who dropped.

Figure 1. Math 005 Final Grade Distribution – Spring 2009

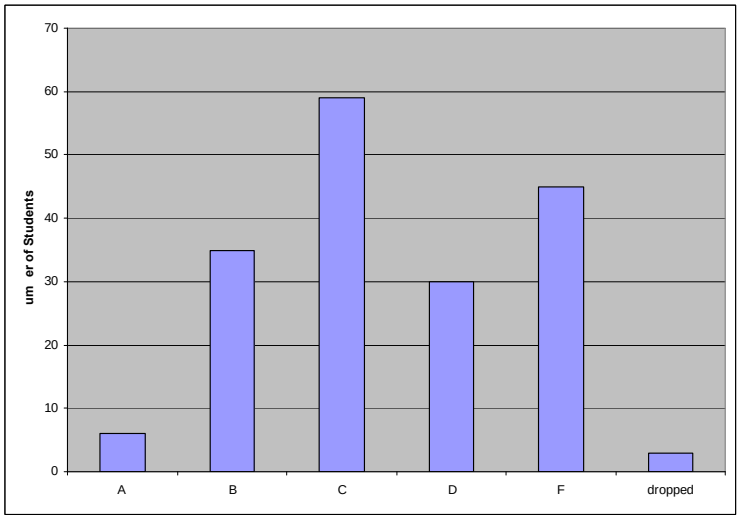


Table 1, below, shows the mid-semester and final pass rates for academic years (AY) 2006-2007, 2007-2008, and 2008-2009. Of notice are the final pass rates of 43.4%, 56.3%, and 57.1% for spring 2008, fall 2008, and spring 2009, respectively. Is the pass rate for Math 5 beginning to level off and if so, what accounts for this level of pass rate? By continuing to collect semester data, we hope to identify components which contribute to or hinder student success and approve upon student learning.

Table 1. Math 005 Mid-semester and Final Pass Rates by Term

Fall	Total	Midterm	Final	Spring	Total	Midterm	Final
2006	177	143 (80.8%)	126 (70.8%)	2007	46	38 (82.6%)	34 (73.9%)
2007	293	186 (62.8%)	209 (71.3%)	2008	129	82 (63.5%)	56 (43.4%)
2008	350	179 (51.3%)	197 (56.3%)	2009	175	113 (63.5%*)	100 (57.1%)

*Based on 178 students

Composition by Major

In an attempt to evenly disburse enrollment numbers in Math 5 across fall and spring semesters, an effort was made to limit fall enrollment to those students whose major required Calculus II and above. Table 2, below, indicates the enrollment numbers in regards to major requirements – those requiring Math 22 or above and those requiring Math 21 or below. Undeclared majors are included as not requiring Math 22 or above.

Table 2. Math 5 semester enrollment by major math requirement.

Semester	Total Enrollment	Number Required Calc. II or above	Number Required Calc. I or below
Fall 2008	339	223 (65.8%)	116 (34.2%)
Spring 2009	175	40 (22.9%)	135 (77.1%)

As you can see from Table 2, the student population in terms of majors was drastically different during fall and spring semesters but both yielded a similar final pass rate. During fall 2008, majors requiring Math 22 or higher composed 65.8% of the Math 5 population and 60.6% of those who failed. During spring 2009, majors requiring Math 22 or higher composed 22.9% of the Math 5 population and only 17.3% of those who failed. During both semesters, the failure rate for these majors was slightly less while the failure rate for students whose major required less than Math 22 was slightly more.

By Section

Viewing final pass rates by section yields the following:

- Section 1 (Bianchi) – 66.7% of 30 passed; 6 repeating students
- Section 2 (Crona) – 58.6% of 30 passed; 2 repeating students
- Section 3 (Crona) – 63.3% of 30 passed; 7 repeating students
- Section 4 (Bianchi) – 46.7% of 30 passed; 13 repeating students
- Section 5 (DaSilveira) – 42.9% of 30 passed; 16 repeating students
- Section 8 (DaSilveira) – 64.3% of 28 passed; 9 repeating students

During spring 2009, 69.7% of students were taking Math 5 for their first time. The two sections with the lowest pass rate, sections 4 and 5, had the highest number of repeating students. We examine repeating student performance across all sections to see if this is a major factor for the failure rate.

Repeating Students

There are 53 students repeating Math 5, 36 of which are freshmen repeating from fall 2008. Repeating students make up 30.3% of the students enrolled and comparably, 33.3% of students that failed. Although only 52.8% of repeating students passed, the failure rate for the course is not highly attributable to repeating students.

Math Placement
Since approximately 70% of students enrolled in Math 5 spring 2009 are taking the course for the first time, we examine the results of the correlation between placement exam scores and final grades. The results are exhibited in Table 3 below.

Table 3. Math placement score, average grade received by student in score range, number of those that failed, and the resulting percent failed.

Placement Score	Total	Average Grade	Number Failed	% Failed
10 or less	39	1.279	20	51.28
11 to 15	50	1.728	19	38.00
16 to 20	25	1.960	5	20.00
21 or more	5	1.600	2	40.00
No Score	56	1.502	29	51.79
Overall Average	175	1.586	75	42.86

As one can see from Table 3, students receiving a score of 10 or below and students with no placement score had the largest percentage of students who failed. Those students who either had or score of 10 or less or had no score at all, make up 54.3% (95 out of 175) of the overall population and 65.3% (49 out of 75) of those students that failed the course. The second largest failing group of students is that which scored between 11 and 15.

Although we are still seeing some predictive qualities between the placement exam score and success in Math 5, it is not as substantial as the one seen during fall 2008 ($R^2 = 0.077$ for spring 2009 and $R^2 = 0.19$ for fall 2008). Of those students enrolled in Math 5 fall 2008 and scoring 10 or less, 69.3% (52 of 75) failed. Only 8 of those 52 students who failed in fall re-enrolled during spring, of which only 3 passed.

Gateways
The Math 5 gateway exam tests students in a variety of basic algebraic and computational skills needed throughout Math 5. The exam is administered within the first four weeks of classes and students are able to take the exam twice a day until the end of the four weeks. The results of spring 2009 semester's gateway exams are as follows.

- 101 students passed, 71.3% of which passed the course
- 54 did not pass, 38.8% of which passed the course
- 21 did not attempt, 28.6% of which passed the course

Not surprising is a higher percentage of students who pass the gateway exam pass the course. Table 4 shows the pass rate for Math 5 per semester along with the number of students not passing or not attempting to take the gateway exam. From the table, it is evident that the likelihood of passing Math 5 having not passed or not attempted the gateway exam is low. Spring 2009 had 62.7% of students who either did not pass the gateway or did not attempt fail the course.

Table 4. Number of students failing gateway exam and Math 5 by semester.

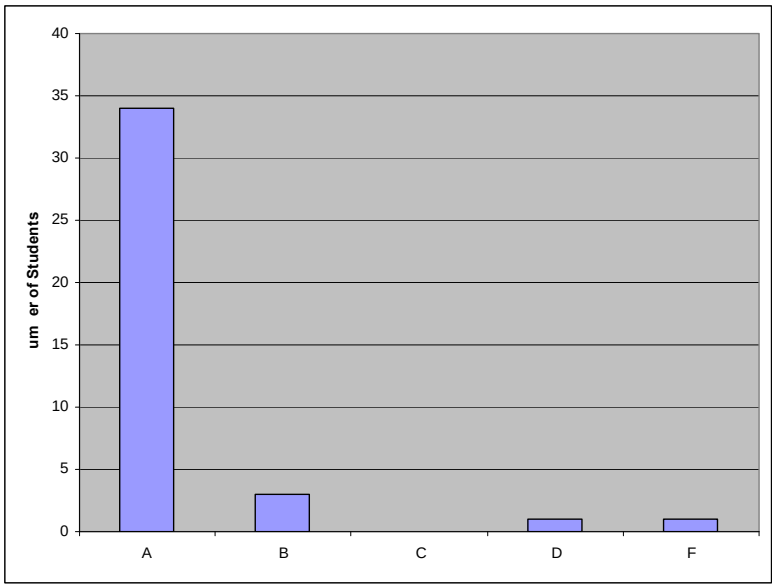
Semester	Math 5 Pass Rate	Gateway Fail or No Attempt	Failed Math 5
Spring 2008	43.4% (56/129)	49 (38.0%)	41 (83.7%)
Fall 2008	58.1% (197/339)	120 (35.4%)	90 (75.0%)
Spring 2009	57.1% (100/175)	75 (42.9%)	47 (62.7%)

The percent of students not passing, including those not attempting the exam, has been 38%, 35%, and 42% for spring 2008, fall 2008, and spring 2009 respectively. Even though there has been a slight increase, it has remained at a rate of approximately 40%. Approximately 30% of students each semester attempt and fail the gateway exam. Thus, the number of students choosing not to take it is not increasing but rather, holding steady.

Math 15: Introduction to Scientific Data Analysis

Of the 40 students enrolled, 94.9% passed. Figure 2 below shows the spring 2009 final grade distribution.

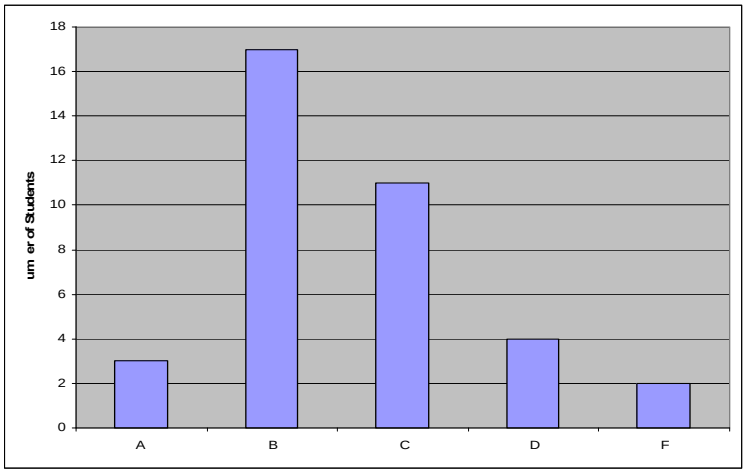
Figure 2. Math 015 Final Grade Distribution – Spring 2009



Math 18: Statistics for Scientific Data Analysis

Of the 37 students enrolled, 83.8% passed. Figure 3, below, shows the spring 2009 final grade distribution.

Figure 3. Math 018 Final Grade Distribution – Spring 2009



Math 21: Calculus I

Of the 266 students enrolled at the end of spring 2009, 57.9% passed. Figure 4, below, shows the spring 2009 final grade distribution.

Figure 4. Math 021 Final Grade Distribution – Spring 2009

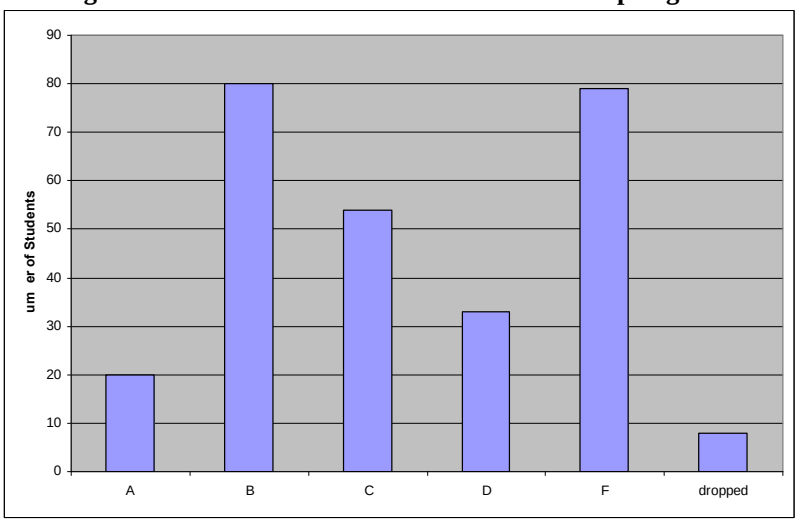


Table 5, below, shows the mid-semester and final pass rate for AY 2006-2007, 2007-2008, and 2008-2009. Enrollment numbers for AY 2008-2009 neared 300 with a final pass rate of approximately 58% each term. In previous semesters, Math 21 final pass rates have varied drastically. We continue to collect semester data to give us insight into why this variance occurs.

Table 5. Math 021 Mid-semester and Final Pass Rates by Term

Fall	Total	Mid	Final	Spring	Total	Mid	Final
2006	234	137 (58.5%)	166 (70.9%)	2007	128	56 (43.8%)	81 (63.3%)
2007	153	109 (71.2%)	83 (55.0%)	2008	213	155 (72.8%)	162 (76.1%)
2008	303	232 (76.6%)	178 (58.7%)	2009	266	168 (61.3%*)	154 (57.9%)

* Based on 274 students

Student Population
Math 21 during spring term is comprised of two primary groups of students – those having previously taken Math 5 during the fall semester and those repeating Math 21 from fall semester. Final semester performance by math backgrounds are as follows for spring 2009.

- Previous Math 5 students
    - 97 (59.5%) of 163 students who passed Math 5 fall 2008 passed
        - 53 (80.3%) of the 66 fall 2008 Math 5 students, who failed Math 21, passed Math 5 with a C+, C, or C-.
    - 7 (53.8%) of 13 students who passed Math 5 during spring 2008 passed
    - 1 (16.7%) of 6 students who repeated Math 5 passed
- 33 (56.9%) of 58 students that are repeating Math 21 from fall 2008 passed
- 10 (58.8%) of 17 students that have not taken a UCM math course passed
- 7 (66.7%) of 9 students taking UCM math courses prior to spring 2008 passed

In spring 2008, previous Math 5 student performance was relatively strong – 80.5% (120/149) passed Math 21. Spring 2009 previous Math 5 performance is comparable to the overall course performance, but would not be deemed "strong" with only 59.5% of the 163 students passing Math 21. Another element important to note is that 80.3% of students who passed Math 5 in fall 2008 with a C+, C, or C- failed Math 21. Furthermore, only 60.9% of students passing Math 5 in fall 2007 with a C+, C, or C- passed Math 21 in spring 2008. It is expected, to some degree, for students that barely pass a course to struggle in the subsequent course, but 80.3% is substantial. It would be beneficial to revisit what it means to get a "C" in Math 5 and note any changes through the semesters.

Course Clustering by Major
Figure 5, below, shows the percent enrolled by major in Math 21 during spring 2009. The following chart, Figure 6, shows the percentage of students failing by major. Figures 5 and 6 are comparable with BIOS and Undeclared having a larger failure rate than the population comprises in Math 21.

Figure 5. Spring 2009 Math 021 Course Enrollment - Percent by Major

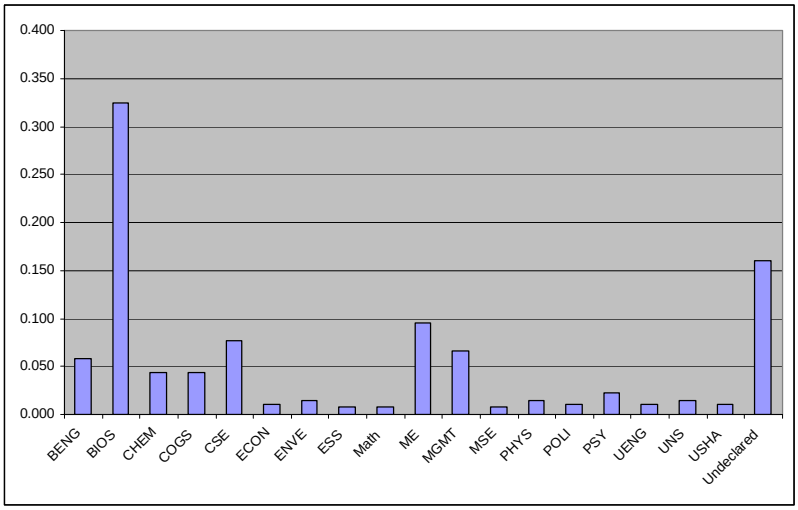
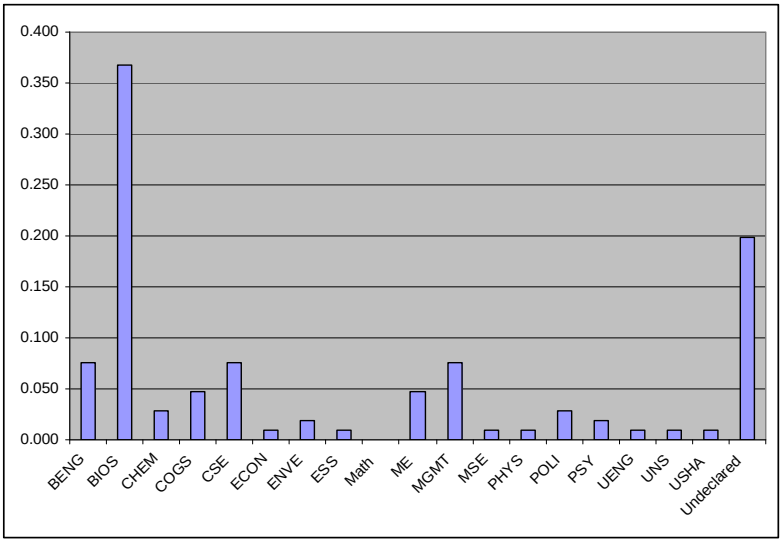


Figure 6. Spring 2009 Math 021 Failure Rates by Major

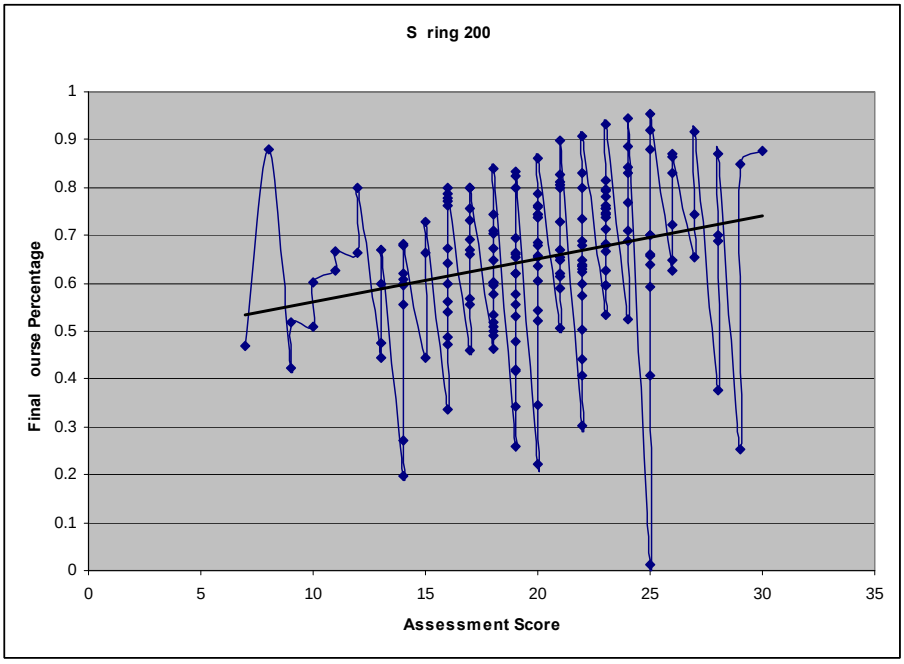


Combining the number of Biology and Undeclared majors shows that these two groups comprise 48.6% of those students in Math 21 and 56.6% of those who failed the course.

Diagnostic Exam

Students are given a 30-question diagnostic exam administered during the beginning of the semester. Below are the results correlating student diagnostic exam scores with the final course percentage.

Figure 7. Spring 2009 Math Diagnostic Exam Score versus Final Course Percentage



A linear regression computed positively correlates with the final course percentage (R^2= 0.063, n = 189). This is, however, less of a correlation than with previous semesters. Specifically, $R^2 = 0.32$, $R^2 = 0.094$, $R^2 = 0.17$ for fall 2007, spring 2008, and fall 2008 respectively. Correlations have been stronger in fall semesters than in spring. Diagnostic exam scores have been collected since fall 2007 and the results are detailed in Table 7.

Since final course percentages translate into different letter grades for different sections and semesters, final course percentage is used.

Table 6. Assessment score, number of students who received particular assessment score, and number who received 60% or higher in Math 21.

Assessment Score	Number of students	Number Receiving 60% or higher in Math 21	
30	2	2	100.00%
29	13	10	76.90%
28	13	11	84.60%
27	25	20	80.00%
26	38	26	68.42%
25	35	28	80.00%
24	64	43	67.20%
23	56	39	69.60%
22	55	39	70.90%
21	46	23	50.00%
20	49	23	46.90%
19	41	18	43.90%
18	89	70	78.70%
17	37	10	27.00%
16	23	10	43.50%
15	20	2	10.00%
14	14	2	14.29%
13	8	3	37.50%
12	5	3	60.00%
11	6	0	0.00%
10 or less	10	0	0.00%

From Table 7, one can see that of the data currently on file, only 24.4% (30 of 123) of students scoring 17 or less on the diagnostic exam have received 60% or higher in the course.

Math 22: Calculus II

Of the 174 enrolled, 76.4% passed Math 22. Figure 8, below, shows the spring 2009 final grade distribution including the 1 student who dropped after mid-semester grades.

Figure 8. Math 022 Final Grade Distribution – Spring 2009

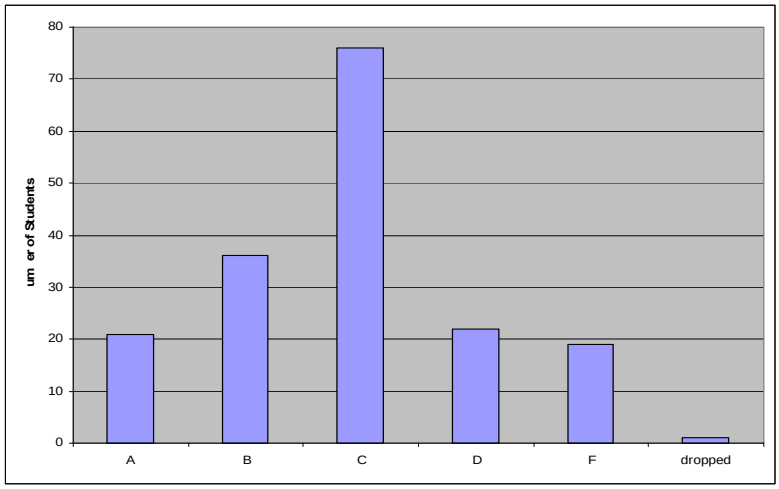


Table 8, below, shows the mid-semester and final pass rate for AY 2006-2007, 2007-2008, and 2008-2009. Math 22 has been fairly consistent over the past 3 academic years. Each year, spring enrollment has been approximately 20 students higher than in fall and pass rates are steady in the mid-70s.

Table 7. Math 022 Mid-semester and Final Pass Rates by Term

Fall	Total	Midterm	Final	Spring	Total	Midterm	Final
2006	113	54 (47.8%)	69 (61.1%)	2007	139	40 (28.8%)	54 (39.1%)
2007	121	102 (84.3%)	93 (76.9%)	2008	136	84 (61.8%)	100 (73.5%)
2008	156	122 (78.2%)	112 (71.8%)	2009	174	144 (82.3%*)	133 (76.4%)

* Based on 175 students

Current course performance by math background is as follows:

- 86.3% (107) of the 124 students that took Math 21 fall 2008 passed
- 37.5% (7) of the 16 students repeating Math 22 from fall 2008 passed
- 66.7% (4) of the 6 transfer students passed
- 53.6% (15) of the 28 students that took Math 21 or ICP prior to fall 2008 passed

Math 023: Vector Calculus

Of the 91 students enrolled, 69.2% passed Math 22. Figure 9, below, shows the spring 2009 final grade distribution including the 1 student that dropped.

Figure 9. Math 023 Final Grade Distribution – Spring 2009

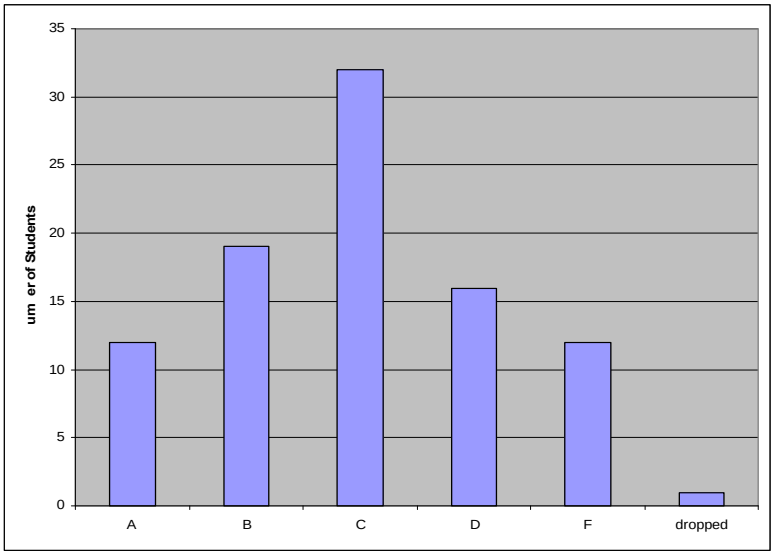


Table 9, below, shows the mid-semester and final pass rate for AY 2006-2007, 2007-2008, and 2008-2009. As you can see from Table 9, fall pass rates have consistently been in the 60s while spring pass rates have varied significantly. AY 2008-2009 has been the steadiest year with pass rates in the mid to upper 60s.

Table 8. Math 023 Mid-semester and Final Pass Rates by Term

Fall	Total	Midterm	Final	Spring	Total	Midterm	Final
2006	45	23 (51.1%)	27 (60.0%)	2007	56	39 (69.6%)	45 (80.4%)
2007	56	37 (66.1%)	37 (66.1%)	2008	56	24 (42.9%)	27 (48.2%)
2008	78	56 (71.8%)	50 (64.1%)	2009	91	57 (62.0%*)	63 (69.2%)

* Based on 92 students

The majority of students enrolling in Math 23 do so immediately following completion of Math 22, although a fair number also enroll in Math 24 prior to Math 23. Here is the performance by student math background for spring 2009:

- 41 students passed Math 22 fall 2008; 82.9% (34) passed
- 15 students passed Math 22 spring 2008; 80% (12) passed
- 25 students took Math 24 fall 2008; 48% (12) passed
- 8 students took Math 23 and Math 24 concurrently; 37.5% (3) passed
- 8 students were repeating Math 23 from fall 2008; 50% (4) passed

A larger percentage of students enrolling in Math 23 immediately following Math 22 are passing than those enrolling in Math 24 before Math 23. Those students taking Math 23 and Math 24 concurrently, albeit only eight, have the lowest percentage of students who passed.

Math 24: Linear Algebra and Differential Equations

Of the 83 students enrolled, 75.9% passed. Figure 10, below, shows the spring 2009 final grade distribution.

Figure 10. Math 024 Final Grade Distribution – Spring 2009

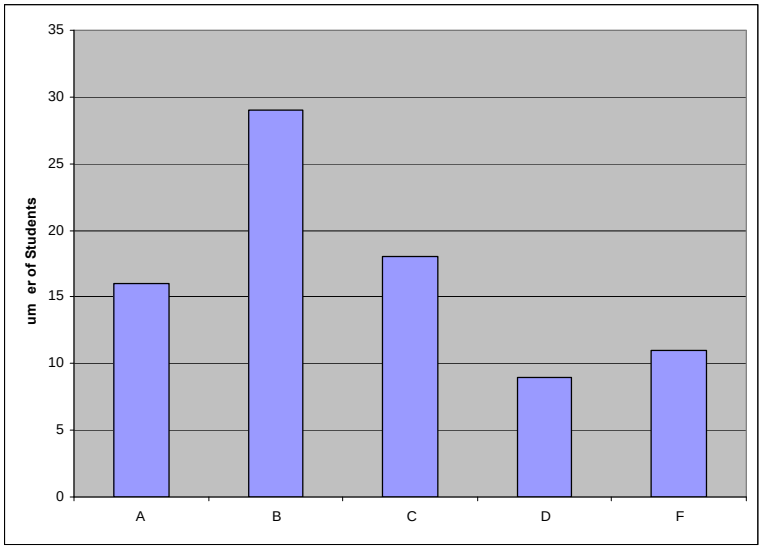


Table 10, below, shows the mid-semester and final pass rate for AY 2006-2007, 2007-2008, and 2008-2009. Math 24 pass rates have been steady at approximately 75% each semester except spring 2006, which had a pass rate of 83.3%.

Table 9. Math 024 Mid-semester and Final Pass Rates by Term

Fall	Total	Midterm	Final	Spring	Total	Midterm	Final
2006	30	26 (86.7%)	25 (83.3%)	2007	31	24 (77.4%)	23 (74.2%)
2007	49	35 (71.4%)	35 (74.4%)	2008	77	56 (72.7%)	58 (75.3%)
2008	71	53 (74.6%)	54 (76.1%)	2009	83	56 (67.5%)	63 (75.9%)

Current course performance by math background is as follows:

- 62.5% (15) of the 24 students that took Math 22 in fall 2008 passed
- 71.4% (5) of the 7 students repeating Math 24 passed
- 100% (24) of the 24 students who took Math 22 spring 2008, Math 23 fall 2008, and now Math 24 spring 2009 passed the course
- 73.3% (11) of the 15 students that took Math 23 in fall 2008 (but not Math 22 in spring '08) passed
- 62.5% (5) of the 8 students concurrently enrolled in Math 23 and Math 24 passed Math 24

Math 30: Calculus II for Biological Sciences

Of the 22 students enrolled, 90.9% passed Math 22. Figure 11, below, shows the spring 2009 final grade distribution.

Figure 11. Math 030 Final Grade Distribution – Spring 2009

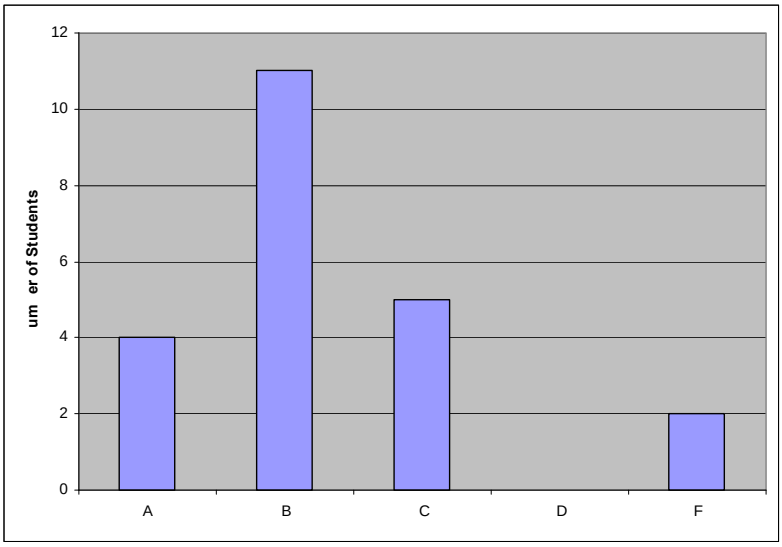


Table 11, below, shows the mid-semester and final pass rate for AY 2006-2007, 2007-2008, and 2008-2009. Math 30's pass rate has remained quite high, although enrollment numbers are decreasing. The final pass rates are averaging in the 80s, with varying mid-semester pass rates. The number of Biological Sciences majors is at a staggering 604, the major with the largest number of students in Natural Sciences. We are seeing, however, a decline in interest in this course even though it is specifically designed for Biology students.

Table 10. Math 030 Mid-semester and Final Pass Rates by Term

Fall	Total	Midterm	Final	Spring	Total	Midterm	Final
2006	10	10 (100%)	10 (100%)	2007	40	35 (87.5%)	34 (85.0%)
2007	27	19 (70.4%)	23 (85.1%)	2008	30	20 (66.7%)	28 (93.3%)
2008	35	23 (65.7%)	30 (85.7%)	2009	22	18 (81.8%)	20 (90.9%)

Math 32: Probability and Statistics

Of the 75 enrolled students, 60% passed Math 32. Figure 12, below, shows the spring 2009 final Math 32 grade distribution.

Figure 12. Math 032 Final Grade Distribution – Spring 2009

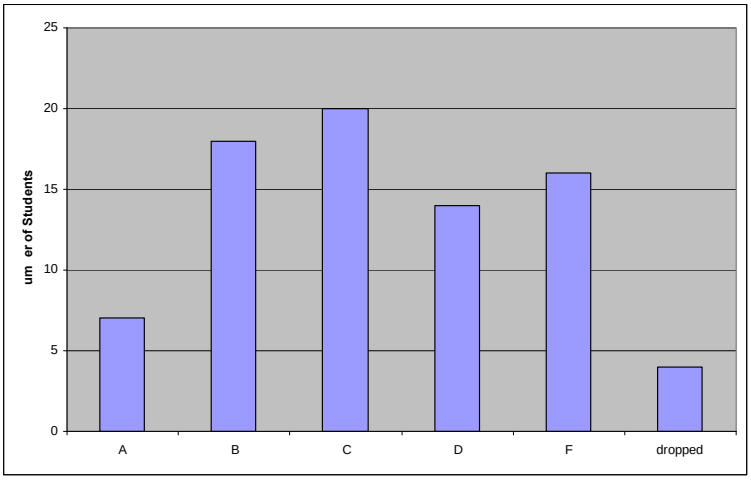


Table 12, below, shows the mid-semester and final pass rate for AY 2006-2007, 2007-2008, and 2008-2009. During fall 2008, Math 32 increased the depth and amount of material covered. We will be tracking student performance in subsequent courses and compare this with data from students who had taken Math 32 prior to the altered course.

Table 11. Math 032 Mid-semester and Final Pass Rates by Term

Fall	Total	Midterm	Final	Spring	Total	Midterm	Final
2006	N/A	N/A	N/A	2007	92	81 (88.0%)	82 (89.1%)
2007	76	69 (90.8%)	74 (97.4%)	2008	80	64 (80.0%)	69 (86.3%)
2008	69	40 (58.0%)	50 (72.5%)	2009	75	51 (64.6%*)	45 (60.0%)

*Based on 79 students

Spring 2009 Mid-Semester Lower Division Mathematics Course Summary
Prepared by Cheryl Hedges
March 24, 2009

Spring 2009 Mid-semester Course Overview

What follows is a brief overview of mathematics courses at mid-semester during the spring 2009 term. Its purpose is to inform mathematics faculty of mid-semester course standings for lower division math courses. For this document, a letter grade of "C-" or higher is considered "passing."

- Math 005 – 63.5% (113 of 178) are passing
- Math 015 – 92.5% (37 of 40) are passing
- Math 018 – 81.1% (30 of 37) are passing
- Math 021 – 61.3% (168 of 274) are passing
- Math 022 – 82.3% (144 of 175) are passing
- Math 023 – 62.0% (57 of 92) are passing
- Math 024 – 67.5% (56 of 83) are passing
- Math 030 – 81.8% (18 of 22) are passing
- Math 032 – 64.6% (51 of 79) are passing

Math 005: Preparatory Calculus

At mid-semester, 63.5% of the 178 enrolled students are passing. Figure 1, below, shows the spring 2009 mid-semester grade distribution.

Figure 1. Math 005 Mid-semester Grade Distribution – Spring 2009

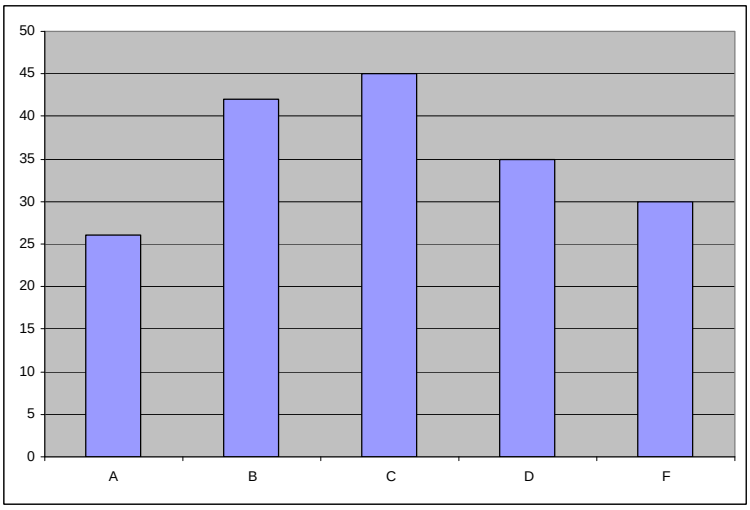


Table 1, below, shows the spring 2009 mid-semester pass rate, as well as the mid-semester and final rates during academic years (AY) 2006 – 2007 and 2007 – 2008. Mid-semester pass rates have been steady for fall and spring semesters of academic years (AY) 2006-2007 and 2007-2008. However, the final pass rate has changed dramatically each semester making accurate predictions of final grades difficult.

Table 1. Math 005 Mid-semester and Final Pass Rates by Term

Fall	Total	Midterm	Final	Spring	Total	Midterm	Final
2006	177	143 (80.8%)	126 (70.8%)	2007	46	38 (82.6%)	34 (73.9%)
2007	293	186 (62.8%)	209 (71.3%)	2008	129	82 (63.5%)	56 (43.4%)
2008	350	179 (51.3%)	197 (56.3%)	2009	178	113 (63.5%)	pending

By Section

Viewing mid-semester pass rates by section yields the following:

- Section 1 (Bianchi) – 67.7% of 31 are passing; 7 repeating students
- Section 2 (Crona) – 60% of 30 are passing; 2 repeating students
- Section 3 (Crona) – 65.5% of 29 are passing; 7 repeating students
- Section 4 (Bianchi) – 46.6% of 30 are passing; 13 repeating students
- Section 5 (DaSilveira) – 56.7% of 30 are passing; 16 repeating students
- Section 8 (DaSilveira) – 85.7% of 28 are passing; 9 repeating students

The majority of students, 70.8% to be exact, are taking Math 5 for their first time. The two sections with the lowest pass rate, sections 4 and 5, have the highest number of repeating students. We examine repeating student performance across all sections to see if this is a major factor for the failure rate.

Repeating Students

There are 52 students repeating Math 5, 36 of which are freshmen repeating from fall 2008. Repeating students make up 29.2% of the students enrolled and comparably, 26.2% of students failing. Thus, the failing rate is not attributable to repeating students. Of the 52 students repeating, 17 (32.7%) are failing at mid-semester.

Gateways

The Math 5 gateway exam tests students in a variety of basic algebraic and computational skills needed throughout Math 5. The exam is administered within the first four weeks of classes and students are able to take the exam twice a day until the end of the four weeks. The results of spring 2009 semester's gateway exams are as follows.

- 101 students passed, 71.3% of which are currently receiving an A, B, or C
- 55 did not pass, 52.7% of which are currently receiving an A, B, or C
- 22 did not attempt, 50% of which are currently receiving an A, B, or C

These numbers are remarkably similar to spring 2008's gateway data. Likewise, spring 2008 had a mid-semester pass rate of 63.5%, equal to this spring term's mid-semester pass rate. However, spring 2008 saw a drastic decline in the number of students passing after mid-semester and finished with 43.4% of students passing the course.

Further Questions

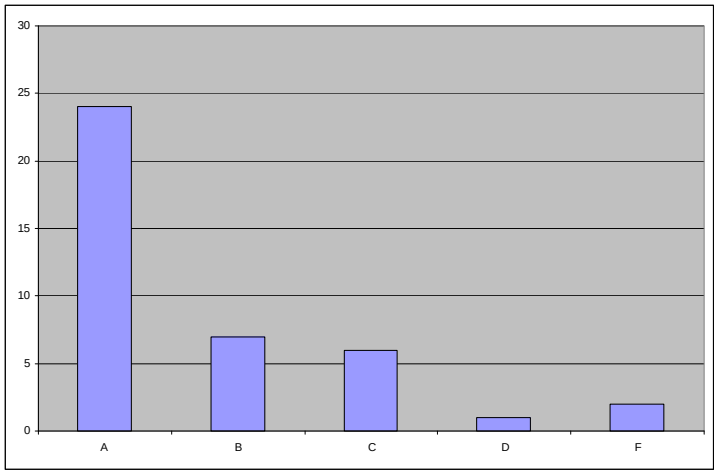
We continue to collect data to help us better understand learning but there are many questions that remain to be answered. In particular, what contributes to the variance each semester from mid-semester to final grades? What happens between mid-semester and final grades that causes pass rates to increases or decreases? Is it attributable to the class structure, teacher, or student? Has there been a change in grading, such as a curve that's

been implemented in some semesters and not in others? Can we attribute this to the student population enrollment (i.e. Math history? Geographical region? First generation? Etc.). This is, of course, a complex answer. Nonetheless, we continue to collect data to look for patterns which will yield insight. Currently, we are gathering enrollment in Math 5 by geographic region to see if this helps us understand the variance from semester to semester. We are awaiting results, which should be available during the final course analyses.

Math 15: Introduction to Scientific Data Analysis

At mid-semester, 92.5% of the 40 enrolled students are passing. Figure 2 (below) shows the spring 2009 mid-semester grade distribution.

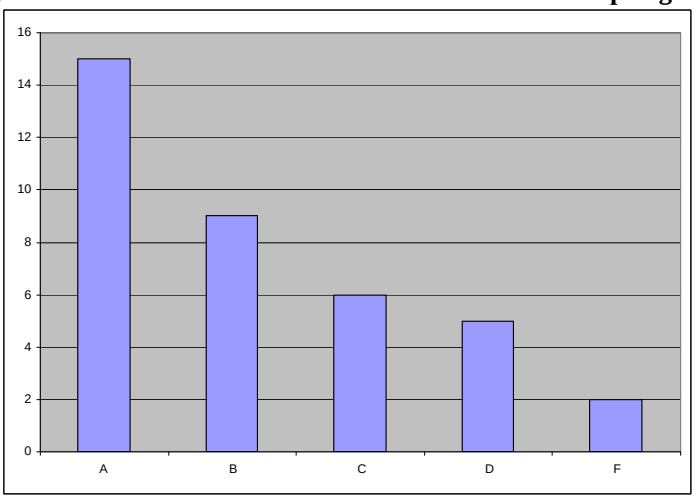
Figure 2. Math 015 Mid-semester Grade Distribution – Spring 2009



Math 18: Statistics for Scientific Data Analysis

At mid-semester, 81.1% of the 37 enrolled students are passing. Figure 3, below, shows the spring 2009 mid-semester grade distribution.

Figure 3. Math 018 Mid-semester Grade Distribution – Spring 2009



Math 21: Calculus I

At mid-semester, 61.5% of the 274 enrolled students are passing. Figure 4, below, shows the spring 2009 mid-semester grade distribution.

Figure 4. Math 021 Mid-semester Grade Distribution – Spring 2009

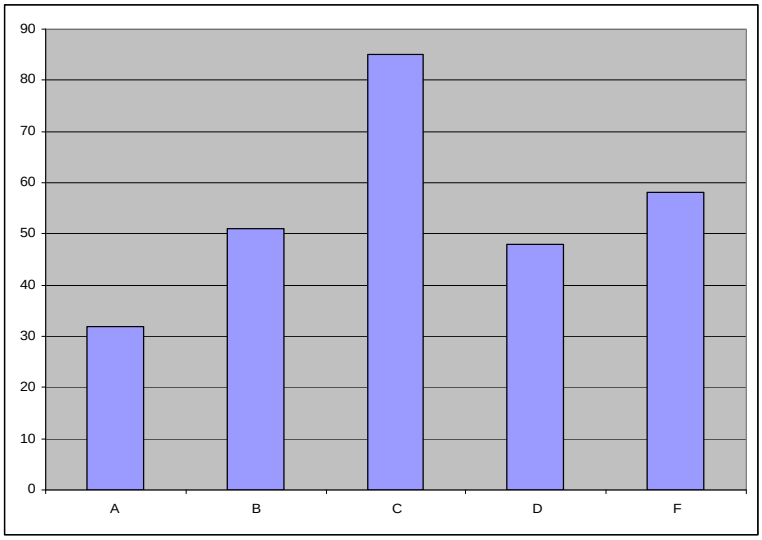


Table 2, below, shows the spring 2009 mid-semester pass rate, as well as the mid-semester and final rates during AY 2006 – 2007 and 2007 – 2008. For the past three semesters, we have seen mid-semester pass rates hover in the 70 percents with the final pass rates varying by term. This spring, however, the mid-semester pass rate is lower than normal – 61.3%. We examine performance by section and student population to gain a better understanding of the issues surrounding this course.

Table 2. Math 021 Mid-semester and Final Pass Rates by Term

Fall	Total	Mid	Final	Spring	Total	Mid	Final
2006	234	137 (58.5%)	166 (70.9%)	2007	128	56 (43.8%)	81 (63.3%)
2007	153	109 (71.2%)	83 (55.0%)	2008	213	155 (72.8%)	162 (76.1%)
2008	303	232 (76.6%)	178 (58.7%)	2009	274	168 (61.3%)	pending

Pass Rates by Section

Table 3, below, shows the total number of students enrolled in Math 21 by section, the percentage of students passing, and the time of each discussion. Large lectures are scheduled from 9:00 – 9:50 A.M. or 10:00 – 10:50 A.M. Monday, Wednesday, and Friday.

Table 3. Spring 2009 Math 021 Enrollment Numbers by Section, Percentage Passing by Section, and Discussion Times

Section	Total	% Passing	Discussion
1	17	0.588	8:00-9:50 AM
2	20	0.550	10:00-11:50 AM
3	19	0.737	1:30-3:20 PM
4	19	0.789	3:30-5:20 PM

5	18	0.500	5:30-7:20 PM
6	20	0.300	7:30-9:20 PM
7	8	0.375	7:30-9:20 AM
8	17	0.471	9:30-11:20 AM
9	20	0.600	11:30-1:20 PM
10	18	0.722	1:30-3:20 PM
11	20	0.650	3:30-5:20 PM
12	19	0.684	5:30-7:20 PM
13	7	0.429	7:30-9:20 PM
14	15	0.800	6:00-7:50 PM
15	20	0.800	4:00-5:50 PM
16	17	0.588	8:00-9:50 AM

The five sections with the lowest percentage passing are indicated in yellow. (To note, two of those sections contain fewer than 10 students which is not adequate to draw any conclusions.) Three of the five lowest performing sections have discussion times that begin either early in the morning (7:30 AM) or late evening (7:30 PM). Speculating, I'd say these sections have poor turnout which would have a large impact on the performance of students in these sections and help to explain the below average pass rate.

Student Population

Math 21 during spring terms is comprised of two primary groups of students – those having previously taken Math 5 during the fall semester and those repeating Math 21 from fall semester. Mid-semester performances by math background are as follows for spring 2009.

- Previous Math 5 Students
  - 89 (61%) of 146 students who passed Math 5 fall 2008 are passing
  - 10 (66.7%) of 15 students who passed Math 5 during spring 2008 are passing
  - 1 (12.3%) of 7 students who repeated Math 5 are passing
- 31 (62%) of 50 students that are repeating Math 21 from fall 2008 are passing Math 21.
- 12 (70.6%) of 17 students that have not taken a UCM math course are passing
- 25 (64.1%) of 39 students taking UCM math courses prior to spring 2008 are passing

Course Clustering by Major

Figure 5, below, shows the number of students enrolled in Math 21 during spring 2009 by major. The following chart, Figure 6, shows the percentage of students failing by major. Figure 5 and 6 are comparable. In other words, Biology majors comprise 32.5% of students in Math 21 and comprise 36.8% of students who are failing at mid-semester.

Figure 5. Spring 2009 Math 021 Course Enrollment by Major

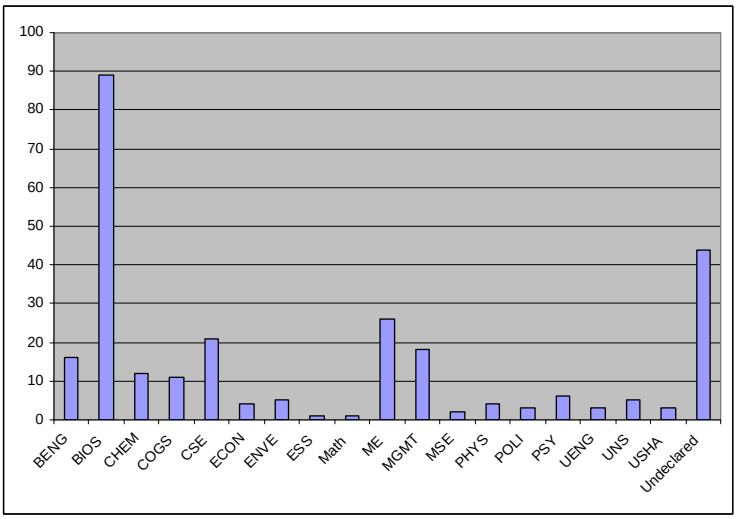
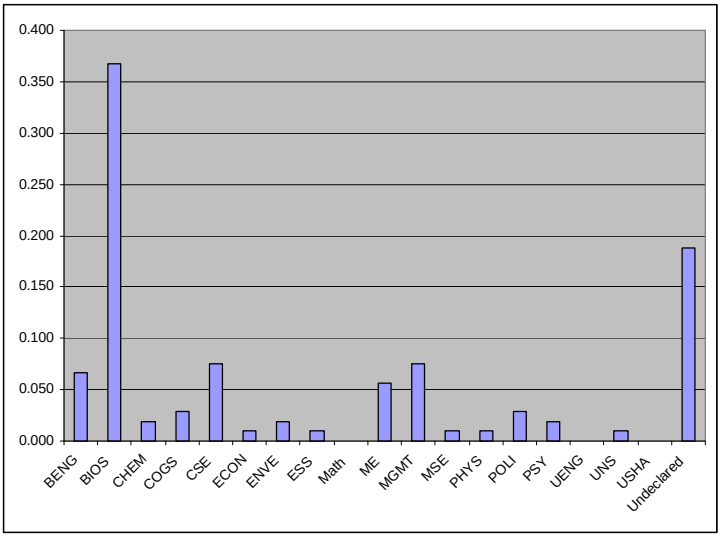


Figure 6. Spring 2009 Math 021 Mid-semester Failure Rates by Major



Combining the number of Biology and Undeclared majors shows that these two groups comprise 48.5% of those students in Math 21 and 55.7% of those who are currently failing.

Math 22: Calculus II

At mid-semester, 82.3% of the 175 enrolled students are passing. Figure 7, below, shows the spring 2009 mid-semester grade distribution.

Figure 7. Math 022 Mid-semester Grade Distribution – Spring 2009

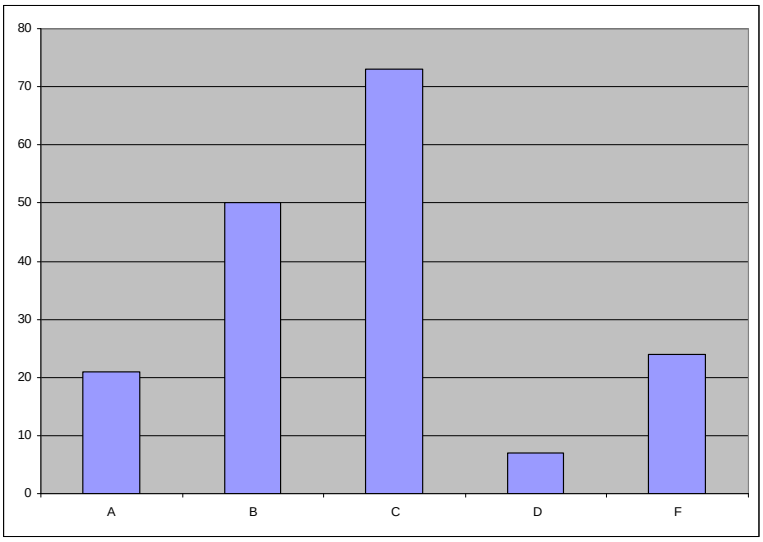


Table 4, below, shows the spring 2009 mid-semester pass rate, as well as the mid-semester and final rates during academic years (AY) 2006 – 2007 and 2007 – 2008. AY 2006-2007 had abnormally low pass rates, but those rates have risen and have remained in the 70s for the past three semesters. With the current mid-semester pass rate of 82.3%, we expect numbers to follow this trend and be in the 70s at the conclusion of spring 2009.

Table 4. Math 022 Mid-semester and Final Pass Rates by Term

Fall	Total	Midterm	Final	Spring	Total	Midterm	Final
2006	113	54 (47.8%)	69 (61.1%)	2007	139	40 (28.8%)	54 (39.1%)
2007	121	102 (84.3%)	93 (76.9%)	2008	136	84 (61.8%)	100 (73.5%)
2008	156	122 (78.2%)	112 (71.8%)	2009	175	144 (82.3%)	pending

Current course performance by math background is as follows:

- 92% (115) of the 125 students that took Math 21 fall 2008 are passing
- 50% (8) of the 16 students repeating Math 22 from fall 2008 are passing
- 66.7% (4) of the 6 transfer students are passing
- 60.7% (17) of the 28 students that took Math 21 or ICP prior to fall 2008 are passing

Math 023: Vector Calculus

At mid-semester, 62% of the 92 enrolled students are passing. Figure 8, below, shows the spring 2009 mid-semester grade distribution.

Figure 8. Math 023 Mid-semester Grade Distribution – Spring 2009

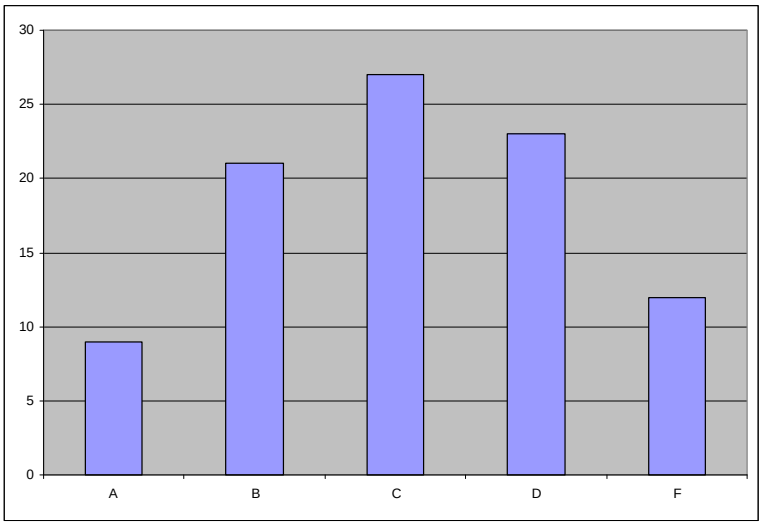


Table 5, below, shows the spring 2009 mid-semester pass rate, as well as the mid-semester and final pass rates during academic years (AY) 2006 – 2007 and 2007 – 2008. Fall pass rates average in the 60s, while spring rates have varied.

Table 5. Math 023 Mid-semester and Final Pass Rates by Term

Fall	Total	Midterm	Final	Spring	Total	Midterm	Final
2006	45	23 (51.1%)	27 (60.0%)	2007	56	39 (69.6%)	45 (80.4%)
2007	56	37 (66.1%)	37 (66.1%)	2008	56	24 (42.9%)	27 (48.2%)
2008	78	56 (71.8%)	50 (64.1%)	2009	92	57 (62.0%)	pending

The majority of students enrolling in Math 23 do so immediately following completion of Math 22, although a fair number also enroll in Math 24 prior to Math 23. Here is the performance by student math background for spring 2009:

- 41 students passed Math 22 fall 2008; 78% (32) are passing
- 12 students passed Math 22 spring 2008; 58.3% (7) are passing
- 21 students took Math 24* fall 2008; 57.1% (12) are passing
- 8 students are taking Math 23 and Math 24 concurrently; 37.5% (3) are passing
- 8 students are repeating Math 23 from fall 2008; 50% (4) are passing

A larger percentage of students enrolling in Math 23 immediately following Math 22 are passing than those enrolling in Math 24 before Math 23. Those students taking Math 23 and Math 24 concurrently, albeit only eight, have the lowest percentage of students passing.

Math 24: Linear Algebra and Differential Equations

At mid-semester, 67.5% of the 83 enrolled students are passing. Figure 9, below, shows the spring 2009 mid-semester grade distribution.

* These students did NOT take Math 22 spring 2008

Figure 9. Math 024 Mid-semester Grade Distribution – Spring 2009

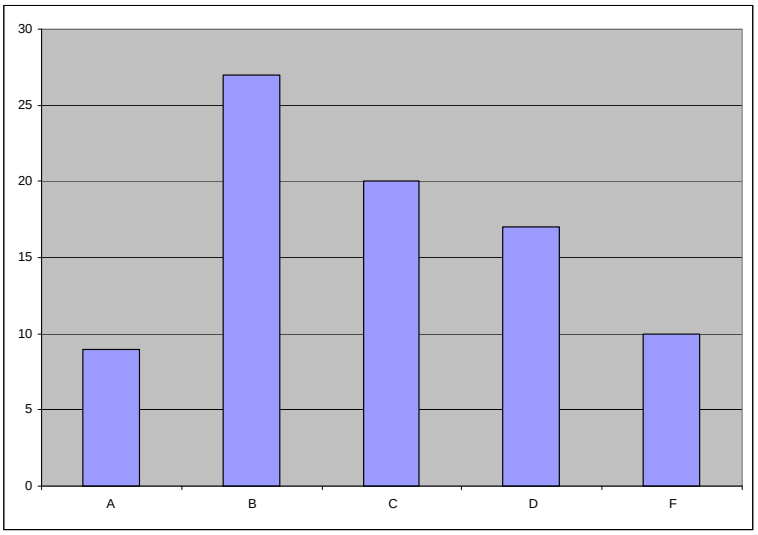


Table 6, below, shows the spring 2009 mid-semester pass rate, as well as the mid-semester and final rates during academic years (AY) 2006 – 2007 and 2007 – 2008. This is one course that has remained fairly consistent each semester. Mid-semester pass rates and final pass rates have been in the 70s each semester except fall 2006, which had pass rates in the 80s. This term's mid-semester pass rate is slightly lower than average at 67.5%.

Table 6. Math 024 Mid-semester and Final Pass Rates by Term

Fall	Total	Midterm	Final	Spring	Total	Midterm	Final
2006	30	26 (86.7%)	25 (83.3%)	2007	31	24 (77.4%)	23 (74.2%)
2007	49	35 (71.4%)	35 (74.4%)	2008	77	56 (72.7%)	58 (75.3%)
2008	71	53 (74.6%)	54 (76.1%)	2009	83	56 (67.5%)	pending

Math 30: Calculus II for Biological Sciences

At mid-semester, 81.8% of the 22 students enrolled are passing. Figure 10, below, shows the spring 2009 mid-semester grade distribution.

Figure 10. Math 030 Mid-semester Grade Distribution – Spring 2009

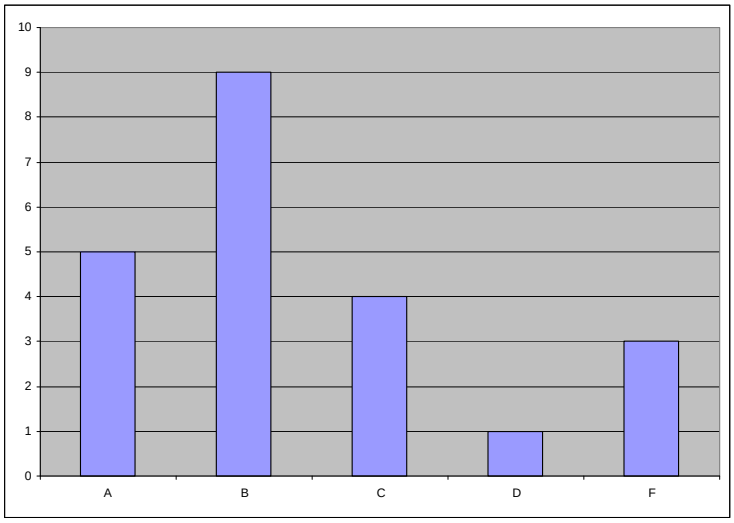


Table 7, below, shows the spring 2009 mid-semester pass rate, as well as the mid-semester and final rates during academic years (AY) 2006 – 2007 and 2007 – 2008. The final pass rates are quite high, averaging in the 80s, with varying mid-semester pass rates. The number of Biological Sciences majors is at a staggering 604, the major with the largest number of students in Natural Sciences. However, we are seeing a decline in interest in this course which is specifically designed for Biology students. I am currently examining how Math 30 students perform in subsequent Biology courses compared to their peers choose to take Math 22. Look for these results in the spring 2009 final course analyses.

Table 7. Math 030 Mid-semester and Final Pass Rates by Term

Fall	Total	Midterm	Final	Spring	Total	Midterm	Final
2006	10	10 (100%)	10 (100%)	2007	40	35 (87.5%)	34 (85.0%)
2007	27	19 (70.4%)	23 (85.1%)	2008	30	20 (66.7%)	28 (93.3%)
2008	35	23 (65.7%)	30 (85.7%)	2009	22	18 (81.8%)	pending

Math 32: Probability and Statistics

At mid-semester, 64.6% of the 79 enrolled students are passing. Figure 11, below, shows the spring 2009 mid-semester Math 32 grade distribution.

Figure 11. Math 032 Mid-semester Grade Distribution – Spring 2009

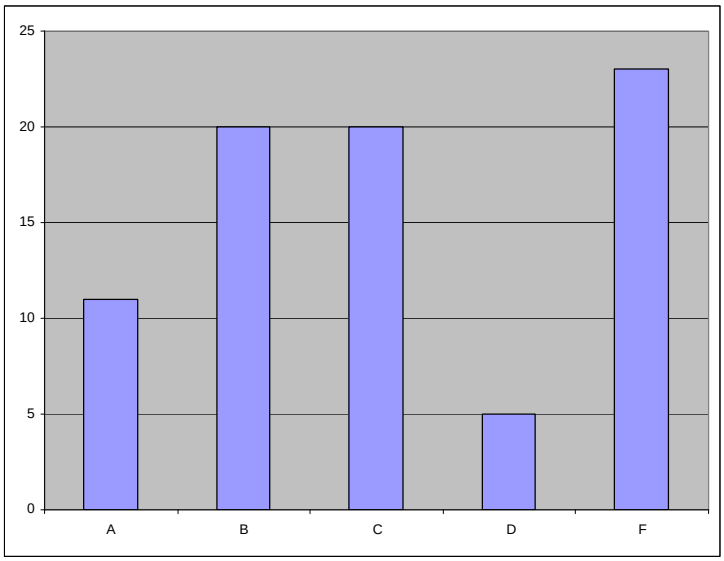


Table 8, below, shows the spring 2009 mid-semester pass rate, as well as the mid-semester and final rates during academic years (AY) 2006 – 2007 and 2007 – 2008. During fall 2008, Math 32 increased the depth and amount of material covered. You can see evidence of this by the lower pass rate. We will be tracking student performance in subsequent courses and compare this with data from students who had taken Math 32 prior to the altered course.

Table 8. Math 032 Mid-semester and Final Pass Rates by Term

Fall	Total	Midterm	Final	Spring	Total	Midterm	Final
2006	N/A	N/A	N/A	2007	92	81 (88.0%)	82 (89.1%)
2007	76	69 (90.8%)	74 (97.4%)	2008	80	64 (80.0%)	69 (86.3%)
2008	69	40 (58.0%)	50 (72.5%)	2009	79	51 (64.6%)	pending