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Principal Investigator Name: Patricia Cerrito

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Proposal Title: Methods to Examine the Gatekeepers to Graduation

1. List of current and pending publications based on the project's findings

- Book, entitled, Investigations of University Expectations Using Text Documents and the Enrollment Database, **Cerrito PB**. Pending with Bentham Science, Inc.
- **Cerrito PB.** Using SAS Enterprise Miner to Examine General Education Issues. SESUG Proceedings. October, 2006.
- **Cerrito PB.** Data Mining Student Performance in Mathematics Courses. CINSUG Proceedings. November, 2006.

Presentations

- **Cerrito PB.** Mathematics as the Gatekeeper to Success, AIR 2006 Forum, Chicago. May, 2006.
- **Cerrito, PB. Invited Address.** Using SAS Enterprise Miner to Examine General Education Issues. SESUG. October, 2006.
- **Cerrito, PB.** Statistics Can Be Online and Hands On. SOTL: Engaging Campus and Community, CPE. May, 2007.
- **Cerrito PB.** Panel Presentation. Data Mining – Concepts, Myths and Case Studies. AIR07. Kansas City. June, 2007.
- **Cerrito, PB.** Statistics is Not a Spectator Sport. Conference on Information Technology. Nashville. November, 2007.
- **Cerrito, PB.** Exploiting the Flexibility of Online Instruction. Conference on Information Technology. Nashville. November, 2007.
- **Cerrito PB.** Panel. Data Mining – Concepts, Myths and Case Studies. Air Forum. Seattle, WA. May, 2008.

2. Demographic information about individuals funded under the grant
   Principal Investigator Name: Patricia Cerrito
   Gender: F
   Race/Ethnicity: Caucasian
   Citizenship: USA
   Disability Status: None

Final Report

Methods to Examine the Gatekeepers to Graduation

Abstract

Many students are enrolled in remedial mathematics; their likelihood of success is small. However, students struggle with mathematics all the way through graduate work, and retention is an issue at all levels. It is the purpose of this paper to examine retention of students through all levels of student effort, and to explore issues that contribute to poor retention. In general education, students are advised into mathematics courses that reflect their majors instead of declaring majors that reflect the level of mathematics skills. Prerequisite material is not well enforced so many students enroll in classes beyond their capabilities. As a result of this analysis, recommendations are made to retain students at the general education level by raising minimum standards to reflect the mathematics required, to retain undergraduate students by having more reasonable expectations in dual enrollment courses, and to retain graduate students by having qualifying examinations more reasonably reflect course material.

Introduction

The purpose of this paper is to examine student retention at all levels of mathematics courses from general education through graduate courses. We use data mining techniques to investigate the data. Initially, the course enrollment studied was for the years 2000-2004. More recently, 2005 enrollment was added; however, the newer data did not change the results. There were approximately 75,000 general education mathematics enrollments during this time period, approximately 550 enrollments in calculus I and II, and 580+ enrollments in mathematics courses beyond calculus. It was found that there are steps that can be taken to retain students at all levels of mathematics study from general education through graduate PhD enrollment. While there are more students enrolled in general education mathematics courses, a higher proportion of students enrolled in calculus leave the university.

General Education Mathematics Students

There are several different mathematics courses that students can use to complete their general education mathematics requirements. Because students may start with remedial courses, and may retake courses due to withdrawals and poor grades, there are too many combinations of courses to examine without some type of level compression. The method of compression is discussed in the appendix. Table 1 gives the results of the compression to ten different categories of general education mathematics enrollment.

Table 1. Categories of Student Enrollment in General Education Mathematics

Cluster Number	Mathematics Courses
1	Trigonometry, Precalculus, Elementary Statistics, College Algebra, Elementary Calculus
2	Remedial Mathematics, Finite Mathematics, College Algebra, Intermediate Algebra
3	Remedial mathematics, Contemporary Mathematics, College Algebra
4	Remedial mathematics, Contemporary Mathematics
5	Mathematics for Teachers, Elementary Statistics, Remedial Mathematics
6	Elementary Statistics, Elementary Calculus, Precalculus, Mathematics for Teachers
7	Elementary Statistics, Contemporary Mathematics, Intermediate Algebra
8	Contemporary Mathematics, Remedial mathematics, Intermediate Algebra, College Algebra
9	Contemporary Mathematics
10	College Algebra, Finite Mathematics

Many of the categories in Table 1 include remedial mathematics courses. The ten categories can be divided into two general groups: courses that are largely algebra based and those that are not. Figure 1 shows the number of enrollments in each cluster; it indicates that the plurality of students begins in Cluster 1, but a high proportion do not graduate (as shown in Figure 2). In contrast, a higher proportion from cluster 7 graduate (non-algebra based) as do those in clusters 5 and 9 (also non-algebra based).

Figure 2. Number of Student Enrollments by Category as Identified in Table 1

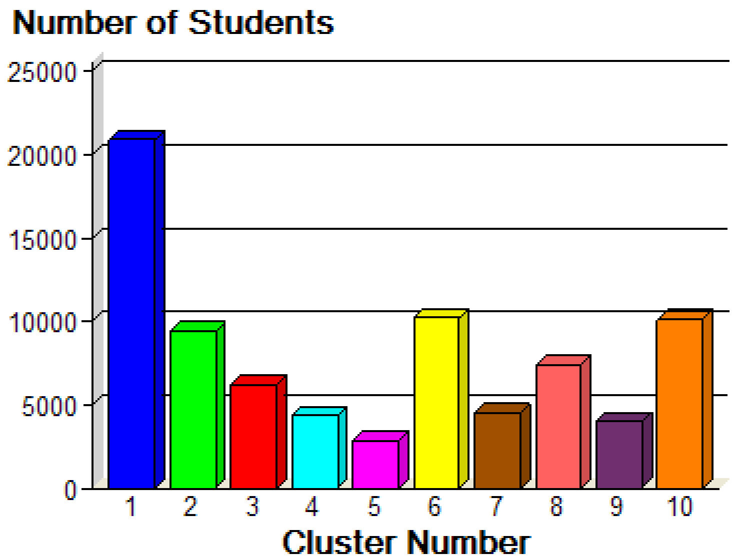


Figure 3. Proportional Difference Between Enrollment and Graduation

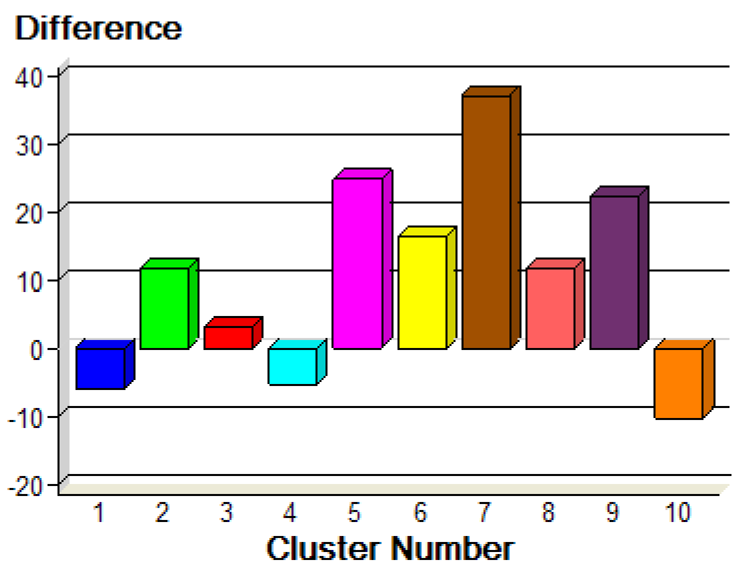
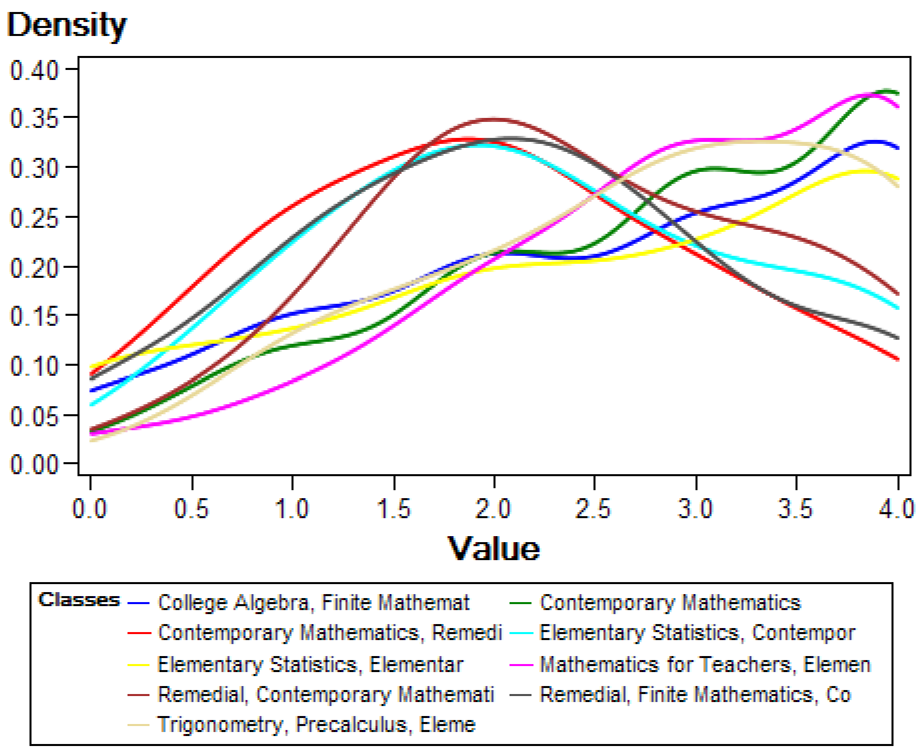


Figure 3 shows the limited grade point average compared to category of mathematics enrollment. It is restricted to students who graduate. The figure demonstrates two clear trends. The first trend shows a steady increase in the likelihood of graduation from a grade of 0.0 to a grade of 4.0, indicating that graduates are much more likely to have a high mathematics grade point average. The second trend peaks at a value of 2.0, indicating that students can perform more poorly in their mathematics course(s) and still graduate. An examination of the clusters indicates that this second trend consists of enrollments in the non-algebra based clusters.

It seems clear, then, that students in majors that require algebra based mathematics must perform at the A-B level in mathematics in order to graduate; those performing at the C or less have a small likelihood of completing their degree.

Figure 3. Probability of Mathematics Grade Point Average for Graduating Students



Recommendations

1. Change admission requirements in majors requiring algebra based courses to more reasonable expectations of success. That is, admission in these disciplines should require a higher minimum mathematics ACT score or a minimum of a B+ in mathematics courses or
2. Change advising practices to publicize the likelihood of graduation success given mathematics ACT score, and grades in prerequisite courses. Suggest students pursue majors in relationship to mathematics skills rather than mathematics courses in relationship to major or
3. Consider changing from a spiral learning model of instruction to a mastery learning model. Students must enroll with a requirement of a minimum number of hours spent on a computer algebra management. Students are dropped from the course if they do not achieve this minimum level. Students must complete a learning module with a mastery score before moving on to a new module. Students must pay tuition for every

semester enrolled, but are given a deferred grade until completion of all learning modules.

Calculus Students

Students should not enroll in Calculus classes without having the necessary background material in algebra. Table 2 shows the enrollment in Calculus by Math ACT score or by previous completion of prerequisite courses. The table indicates that many students do enroll in Calculus without the required algebra skills. Figure 4 shows that most of these students will fail in Calculus.

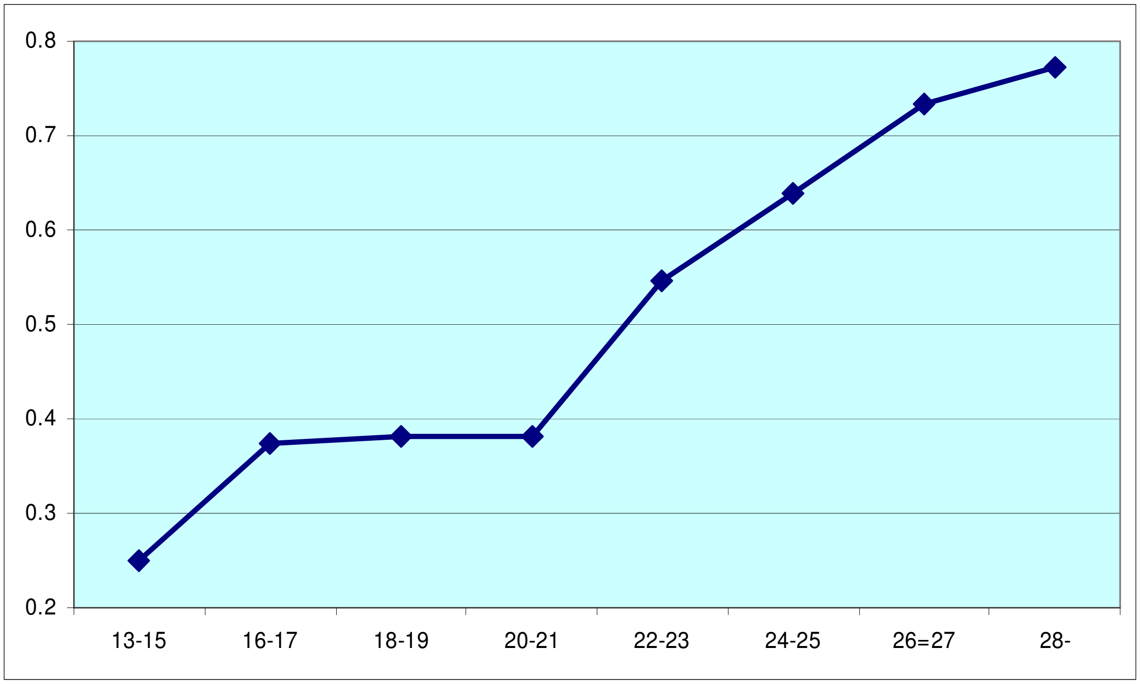
Table 2. Calculus Enrollment by ACT Score

ACT Level	Enroll in Calculus Without Prerequisites	Enroll in Calculus With Algebra	Enroll in Calculus with Precalculus
13-22	18	75	35
23-24	28	43	38
25-26	70	11	85
27-	133	4	15

Low performance in Calculus occurs when students have low math ACT scores independent of whether they have completed the required prerequisite courses to gain background in algebra. The success rate only climbs above 50% when students have at least a minimum Math ACT of 22-23. The success rate increases to 70% when students have a minimum Math ACT of 26-27. The minimum required for enrollment is 27.

Science and Mathematics majors are generally required to take at least one semester of Calculus. Many students in Engineering also enroll in Calculus, although Engineering also offers its own Calculus sequence.

Figure 4. Success in Calculus (Grade A,B,C) by ACT Score



However, students will not be successful in calculus unless they have the necessary algebra background. Unfortunately, many students enroll in calculus lacking these skills. Table 3 gives the proportion of students who leave the University by their level of mathematics instruction. The table indicates that a higher proportion of students in Calculus will leave compared to students enrolled in General Education. Students who declare a mathematics major while enrolled in General Education are very likely to change their majors, or to leave. This result reinforces the recommendation that a mathematics major should have a higher minimum math ACT.

Table 3. Proportion of Students Leaving University by Level of Instruction

Starting Course Level	Proportion Changing Majors	Proportion Leaving University
General Education	53%	18%
Precalculus	10%	15%
Calculus I	20%	23%
Calculus II	32%	21%

Recommendation

1. Enforce prerequisites for calculus enrollment or
2. Have students take a placement exam prior to (or during) the first class period, and withdraw any student who does not demonstrate proficiency in algebra.
3. Pre- and Post-test students in the algebra prerequisite to calculus to ensure that they have the necessary background. Only students who have made sufficient progress can advance to calculus.

Mathematics Majors

Students who major in mathematics are required to complete a number of dual-enrollment courses. Faculty are to identify in course syllabi expectations of additional work, or higher standards for graduate students in the course when compared to undergraduate students. As shown in Table 4, success rates (grade of A,B,C) are high (64%) at the 300-level, increasing to 82% at the 400-level. This is as expected since marginal students will change majors, or leave the University so that only the top students advance to the 400-level. These will also be students who have known only academic success.

However, as shown in Table 5, grades for undergraduates are considerably lower compared to those for graduate students in the dual enrollment, 500-level courses.

Table 4. Success Rates by Course Level

Course Level	A	B	C	D	F	W
300	26%	19% 64%	19%	7%	16%	12%
400	48%	22% 82%	12%	2%	5%	10%
500	32%	20% 61%	9%	5%	10%	21%
600	71%	11% 82%	2%	1%	1%	8%

Table 5. Success Rates in Dual-Enrollment Courses

Grade	BA Degree	BS Degree	MA Degree
A	25%	21%	60%
B	26% 62%	11% 45%	18% 78%
C	11%	13%	3%
D	5%	3%	0%
F	12%	15%	1%
W	21%	37%	14%

With success defined as receiving an A,B, or C in the course, graduate students have a 78% success rate compared to a 45% rate for students pursuing the BS degree and 62% for students pursuing a BA degree. There are some questions that need to be considered here:

1. Why is there a difference in success rates between BA and BS students?
2. What is the impact of this grade differential on student retention?
3. Do other departments also have disparate grading between graduate and undergraduate students that can impact outcomes and retention?

In order to examine the difference between BA and BS students, we must first identify the course requirements that differentiate the two degrees. The courses required for the undergraduate options are

- BA: Algebra I, Analysis I, 2 electives
- BS: 4 possible options that all include Algebra I, Analysis I, 2 electives
    - Probability, Statistics, Probability Models
    - Modeling I,II
    - Data analysis, Probability, Statistics, Probability Models or Sampling
    - Analysis II, Algebra II, Probability

Students enrolled in the BA option take only two dual-enrollment courses while students in the BS must take a minimum of four such courses. Moreover, students in the MA program are considered deficient if they have not completed Analysis I,II and Algebra I,II. Therefore, Analysis I and Algebra I have primarily undergraduate enrollment while the other courses have considerably higher rates of graduate enrollment.

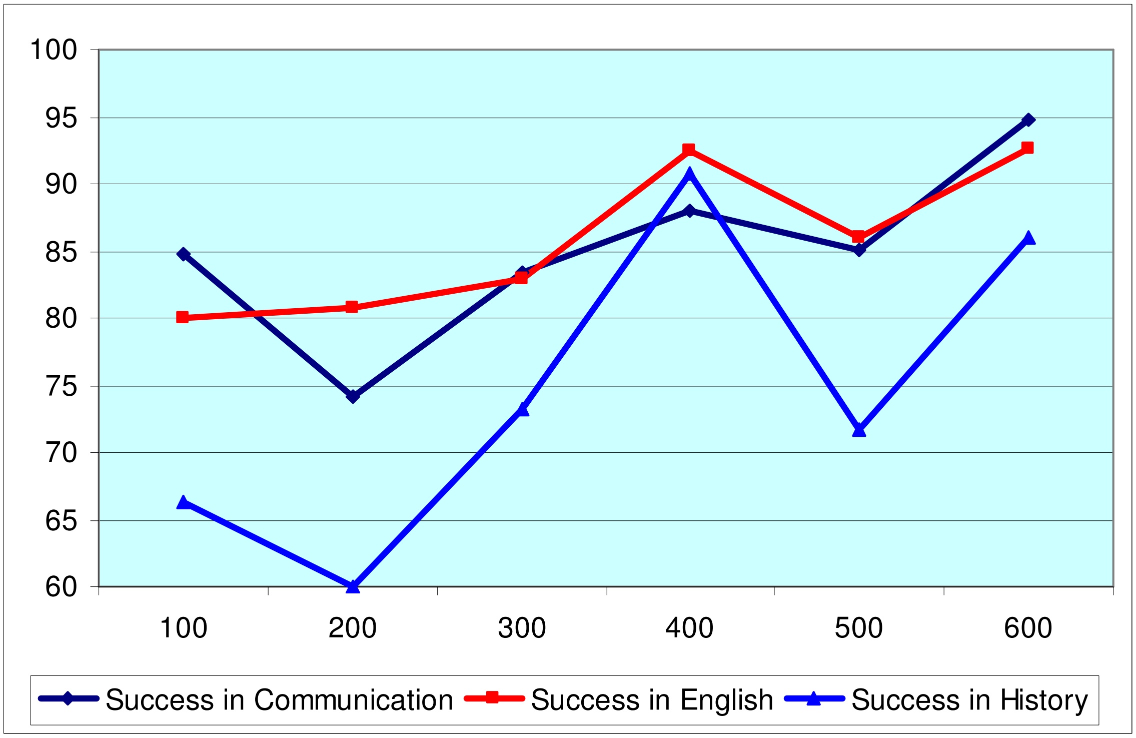
Table 6 examines the graduate rate compared to the grades received. At the 500-level, 80% of undergraduates who receive an A, and 76% of those who receive a B graduate. However, only 27% of those who receive a D or F, and 20% of those who drop the course graduate with a degree. Therefore, the practice of dual-enrollment penalizes undergraduate students and reduces the retention rate and the graduate rate. Since 55% of BS students do not succeed at the 500-level, and fewer than 25% graduate, retention is low for students in their senior year of mathematics instruction.

Table 6. Graduation by Grade in Course Level

Course Level	Graduation Rate for A grades	B grades	C grades	D,F grades	**W grades**
100	36%	30%	18%	0%	50%
200	65%	0%	0%	41%	0%
300	76%	49%	37%	20%	46%
400	100%	0%	0%	0%	0%
500	80%	76%	100%	27%	20%
600	100%	100%	100%	0%	0%

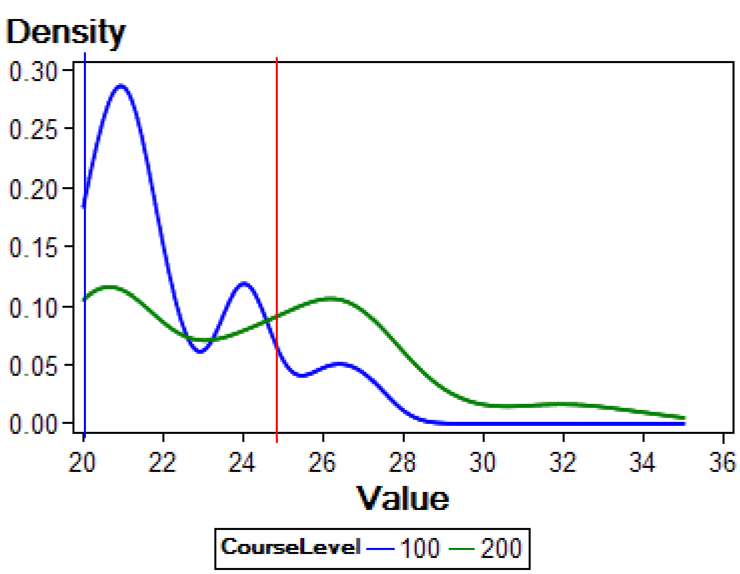
Three non-mathematics departments were considered by course level (Figure 5). The dip in success rates at the dual-enrollment (500) level are apparent. This trend appears to be quite common across departments, and should be a concern across the University, not just in mathematics.

Figure 5. Non-Mathematics Departments with Lower Success Rates in Dual Enrollment Courses



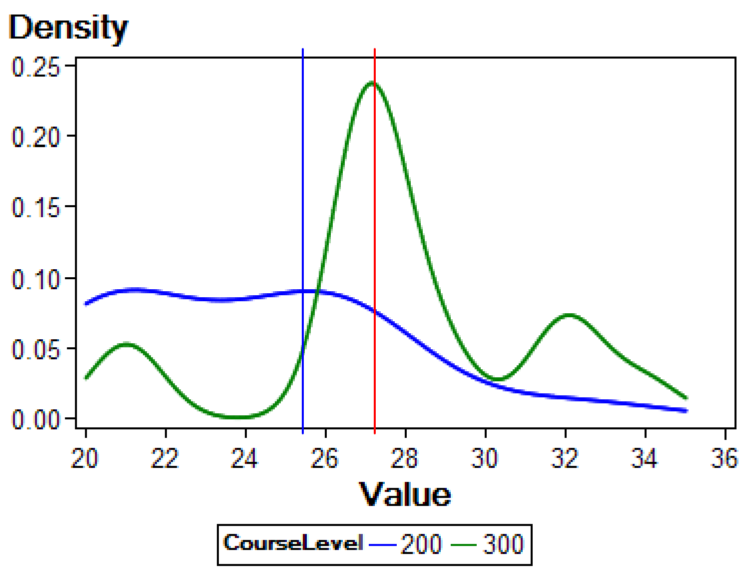
We must also consider the characteristics of students in the major. For example, consider the ACT math scores for students in 200-500 level courses (Figures 6-9).

Figure 6. Distribution of Math ACT Scores for 100-200 Level Courses (General Education and Calculus I,II).



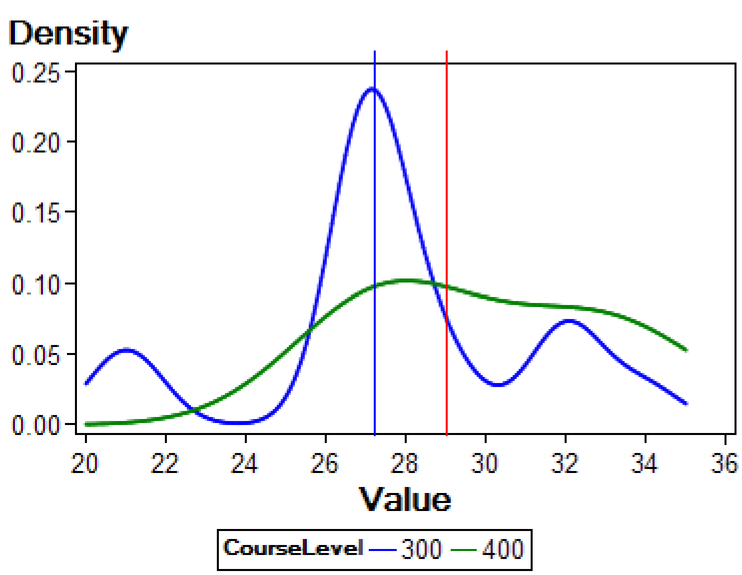
The primary peak for the general education courses is at an ACT value of 21; the primary peak for calculus is at 26, still one point lower than the prerequisite requirement of a 27 or higher. The General Education minimum is 21 for the Contemporary Mathematics course offered mostly for Humanities majors; a minimum of 23 is required for College Algebra. It is clear that many students enroll without sufficient background strength in Mathematics.

Figure 7. Distribution of Math ACT for Calculus Level and 300-Level Courses (Calculus II, Linear Algebra, Introduction to Proofs).



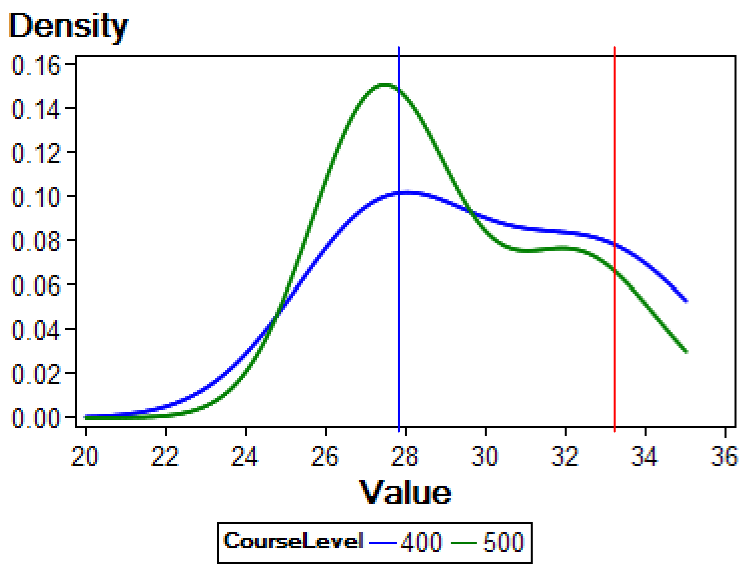
By the time students advance to the 300-level, the peak math ACT value is equal to 27, which is the minimum requirement for Calculus enrollment. Very few students with a lower math ACT advance to 300-level courses.

Figure 8. Distribution of Math ACT for 300- and 400-Level Courses (Differential Equations, Introduction to Analysis)



By the 400-level, approximately half of the students have a math ACT of 29 or better, indicating that students with the minimum of 27-28 start to struggle.

Figure 9. Distribution of Math ACT for 400- and 500-Level Courses (Dual Enrollment)



Since graduate students record the GRE rather than ACT scores, Figure 9 only includes undergraduates. By the 500-level, the probability is very high that students have the minimum or higher required Math ACT. It seems clear, that students with insufficient math ACT are not going to be successful in completing the mathematics major.

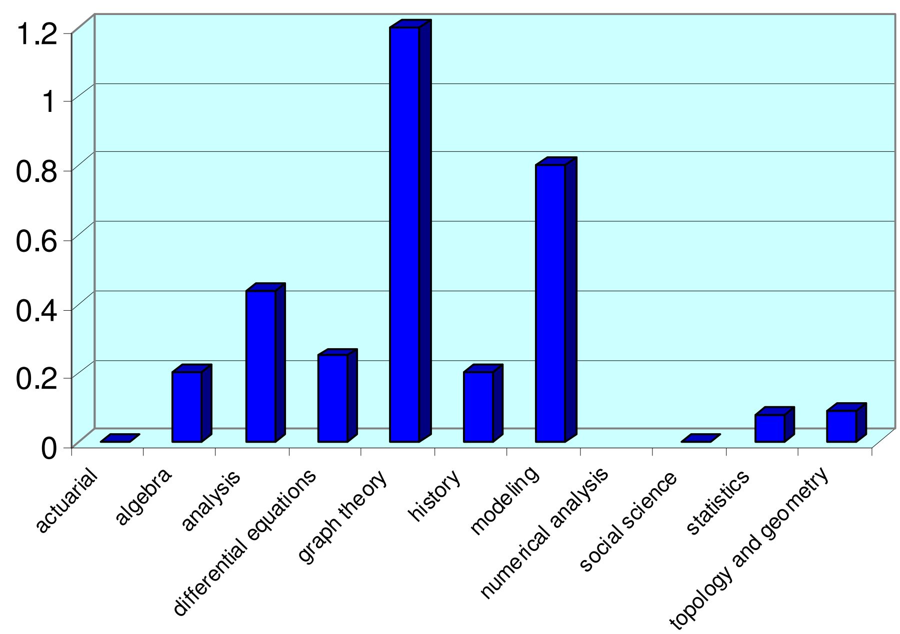
To examine student interests, their mathematics course enrollments were grouped using text analysis (Table 7). Text strings of all course enrollments were created, one for each student. Then the text strings were clustered to determine whether student interests could be discerned. A total of ten clusters were defined through the text mining process. Labels indicate that student interests can be identified. Most undergraduate students demonstrate interest in applied options in the BS Major. Most prevalent is the option for Actuarial Science, although students do differ in their choices of electives.

In contrast, Figure 10 shows a ratio of the number of faculty in a particular mathematics discipline to the number of courses taught in the same subjects. The Figure indicates that there are fewer faculty in the most popular student choice of Actuarial Science with only one additional faculty member in probability and statistics. This can be a source of frustration for students who want to take available options that are not regularly offered in the curriculum, another reason for students leaving in the senior year.

Table 7. Student Enrollments in dual enrollment and graduate courses

Courses	Frequency	Label
Advanced Euclidean Geometry, Abstract Algebra I, Selected Topics, History of Mathematics, Abstract Algebra II	87	BS in Pure Mathematics
Geometry, Introduction to Data Analysis, Abstract Algebra I, An Overview of Mathematics, Analysis I	37	BA
Introduction to Data Analysis	64	BS in Probability and Statistics
Modeling I, Modeling II, Actuarial Science I,II,III	44	BS in Actuarial Science
MA Thesis, Seminar in Applied Analysis, Advanced Abstract Algebra II, Seminar in Teaching Mathematics, Combinatorics I	52	MA
Selected Topics in Mathematics	30	Non-Majors
Modeling I, Modeling II, Advanced Analysis I, Combinatorics I, Seminar in Teaching Mathematics	78	MA-PhD
Analysis I, History of Mathematics, Algebra I, Discrete Mathematics for Math Education MAT, Introduction to Partial Differential Equations	95	Masters in Education
Complex Analysis, Algebra II, Analysis I	13	BS in Applied Mathematics
Probability, Statistics, Actuarial I, II, Partial Differential Equations	84	BS in Actuarial Science

Figure 10. Ratio of Faculty Specialty to Course Offerings



Recommendations.

1. Require a minimum math ACT for declaration of a major in mathematics.
2. Monitor Departments with dual enrollment courses to ensure that undergraduate students are not penalized in course grades by faculty expectations that they will perform at the level of graduate students. The key is to look at success rates to determine whether there is a dip in grades at the dual-enrollment level and then to compare undergraduate grades to graduate grades. If undergraduates are penalized, develop procedures to ensure that faculty understand the need for different expectations for undergraduates compared to graduate students.
3. Hire faculty to teach more courses in the students' areas of interest.

Mathematics Graduate Students

Students in the MA program must enroll in two out of six possible 2-course sequences; students in the PhD must enroll in four out of six, with two from the group: analysis, algebra, combinatorics and two from the group: modeling, probability and statistics, and applied statistics. In addition, MA students must complete 12 additional hours, not necessarily in mathematics while PhD students must complete 18 additional hours. To complete the MA, students must pass one general written examination, two of the PhD qualifying examinations, or write a thesis; in the PhD, students must complete three qualifying examinations, one internship, one substantive computer project, and a dissertation. Both graduate programs are intended for students who want to be employed in industry rather than academia. Table 8 shows the enrollment for these course sequences. Table 9 shows success in qualifying examinations.

Table 8. Enrollment in Course Sequences

Course Sequence	Semester I	Semester II	Percent Dropoff
Analysis I,II	58	30	48
Algebra I,II	50	14	72
Combinatorics I,II	53	12	77
Modeling I,II	43	29	32
Probability, Statistics	39	20	49
Applied Statistics I,II	21	13	38

Students completing only one semester of the course sequence will not complete a graduate degree. The success rates are relatively low and can vary considerably. In the fall semester, 2003, advanced Analysis I had 76% A grades, which fell to 9% in the fall of 2004. In the fall of 2004, the success rate was only 32% compared to 81% the year before. Similarly, the success rate in Advanced Algebra I was 54% in 2002 compared to 91% in 2004. The same inconsistency occurs in Advanced Combinatorics (66% success in 2000 compared to 81% in 2002 and 78% in 2004). However, a 78% success in Combinatorics does not translate to success in the qualifying examination (0%) in 2004.

Table 9. Success in Qualifying Examinations

Exam	Algebra	Analysis	Combinatorics	Prob & Statistics	Applied Statistics	Modeling
May, 2003	80%	____	50%	100%	____	____
October, 2003	50%	____	50%	____	____	____
May, 2004	100%	75%	0%	____	100%	91%
October, 2004	____	0%	0%	____	100%	____
May, 2005	100%	75%	73%	____	____	____
October, 2005	100%	100%	33%	____	____	____
# Students Attempted	21	16	20	1	8	11
# Students Passed	19	13	12	1	8	11
Percentage Passed	90%	81%	60%	100%	100%	100%

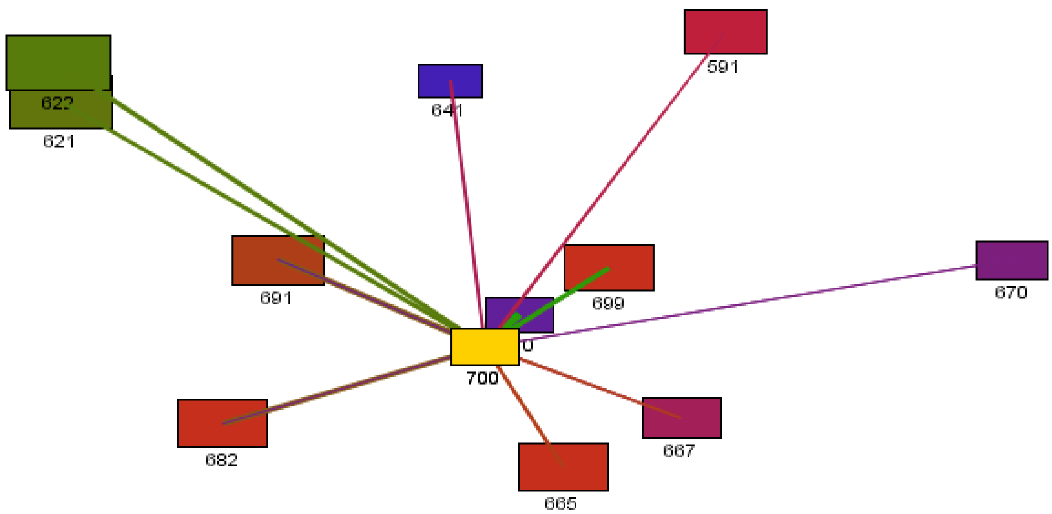
Table 9 indicates considerable variability in the passing rates for the exams; consistency is more likely in the applied exams of Probability & Statistics, Modeling, and Applied Statistics compared to the core mathematics exams. The passing rates also differ considerably from exam to exam. Table 10 gives the progress for individual students.

Table 10. Progress of Graduate Students in Exams

Year Started Exams	Number of Students Started	Number of Students Completed	Number No Longer Enrolled (Without Graduation)
2002-2003	8	5	2
2003-2004	16	5	6
2004-2005	6	2	1
2005-2006	6	0	2

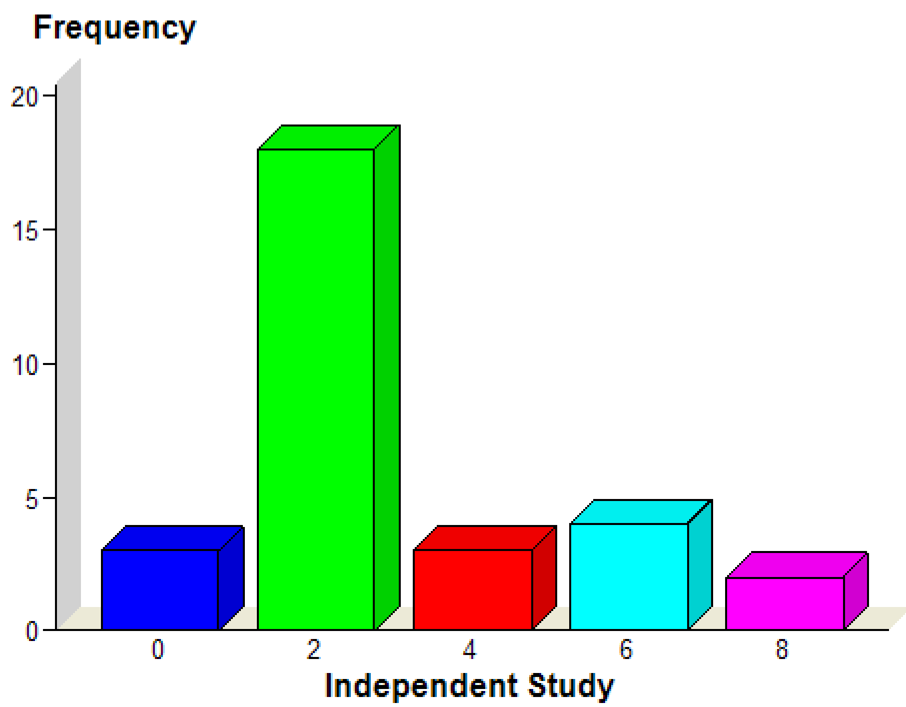
Figure 11 gives the link analysis showing the lift for connections to Math 700, dissertation research. Life is defined by the equation, Lift = confidence/expected confidence where confidence is defined by the number of students with courses A and B divided by the number of students with course A. The expected confidence is equal to the number of students enrolled in course A divided by the number of students. Figure 11 shows that students who advance to dissertation level do so by completing the Combinatorics sequence (681,683) and Algebra (621,622) instead of the Analysis sequence (601,602).

Figure 11. Link Analysis of Relationships to Dissertation Courses



Students who advance to dissertation also enroll in Math 691, independent study. Figure 12 gives the number of independent study courses by student. These courses prepare students for dissertation research while they are still completing qualifying examinations.

Figure 12. Number of Independent Study Courses



Recommendation.

1. Reduce the variability in course grading so that students don't have the "luck of the draw" and can have reasonable expectations concerning course standards. Similarly, the success in the qualifying examinations should have some relationship to performance in the course.

2. Conduct exit exams with graduate students leaving the University to determine whether the reasons are positive or negative.

Discussion

In many cases, focus has been on the retention of first year students to the second year. However, this study demonstrates that retention needs to be of concern at all levels of a student's career at the University. Students with high ACT scores and low risk factors are also leaving the University before graduation.

At the more advanced course levels, concern has to shift from student preparation to faculty practices, particularly in grading. While it is long recognized that there are "hard graders" and "easy graders", lack of consistency in grading habits can be detrimental to student retention. While consistency is of importance in business and industry, there is no quality control, and no attempt at consistency in grading patterns. Instead, teaching quality is determined almost exclusively based upon student teaching evaluations. These evaluations cannot provide quality control across classrooms because of too many confounding factors.

However, faculty autonomy will not generally permit a more general development of examinations in upper division classes. In fact, consistency in grading practices is not a concern at the University level. Universities need to consider whether consistency is a practice that needs to be pursued.