Increasing Students' Mathematical Competence By Developing an Interactive Instructional Context for Math 2 and Math 3

FINAL REPORT

June, 2005

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BACKGROUND

The mantra bemoaning the lack of basic mathematical competence exhibited by many incoming university freshmen is pervasive on most American university campuses including the University of California, Santa Cruz. Effectively assisting students to demonstrate mathematical competence at the pre-calculus level has become a serious educational and financial challenge at UCSC. Although three years of college preparatory mathematics is required of students admitted to UCSC, each academic year over 1,600 students enroll in Math 2 and Math 3, both courses at the pre-calculus level (covering curriculum reflective of high school, UC articulated Mathematics courses). Math proficiency at the post Math 3 level is required of students pursuing majors in the Biological and Physical Sciences, Computer Science, Engineering, Economics, Psychology and Sociology. Yet, the no/pass rate in these pre-calculus classes has consistently been an average of just over 25% in Math 2 and from 20 to 25% in Math 3 except for a few quarters where the Math 3 pass rate was very high. One might speculate that the occasional dramatic differences in Math 3 are due to teacher effect in this course which is taught by several different faculty members, whereas the Math 2 course has been taught by the same instructor for the past several academic years.

During the 2000-2001 academic year, Learning Support Services (LSS) began the Modified Supplemental Instruction (MSI) program, attaching peer-guided learning groups to Math 2 and Math 3. The MSI Learning Assistants are paid to attend the lectures in order to be clear as to the course content and the professor's expectations. They then schedule interactive group learning sessions which students voluntarily attend. Although the students who chose to attend MSI had a higher pass rate in Math 2 and Math 3 classes than the students who did not choose to attend MSI, the no pass rate in the Math 2 and Math 3 classes continued to be over 20%, closing the gate to majors for many students.

Therefore, Learning Support Services and the Mathematics Department applied for and received a grant from the Committee on Teaching in order to design and implement a multi-faceted curriculum development and instructional delivery program to increase students' academic success in Math 2 and Math 3. The major goal of the grant-funded program was to facilitate students' success in Math 2 and Math 3 classes. In order to meet this goal the following objectives were developed to investigate and address students' apparent educational needs.

> To improve the quality of learning support offered to students by integrating peer guided learning into small discussion sections and Modified Supplemental Instruction groups, and carefully and systematically train and monitor

undergraduate teaching assistants to ensure their ability to assist students to become thoughtful and effective independent problem solvers.

To conduct an extensive study of students' academic performance in Math 2 and Math 3 based on performance patterns on the Mathematics Placement Exam (MPE), course mid-term and final examinations, and information regarding typical high school math curricula.

To make curricular and pedagogical modifications to the courses based on students' apparent needs and course objectives and expectations.

The remainder of this report will discuss progress toward these three objectives, focusing on data gathered regarding students' apparent readiness for Math 2 or Math 3 and its relationship to their course performance, the training and evaluation of the undergraduate teaching/learning assistants, and the observations and suggestions of the Mathematics instructors regarding curriculum and pedagogical issues.

ANALYSIS OF STUDENTS' PREPAREDNESS AND COURSE PERFORMANCE DATA

Prior to fall, 2002, the Mathematics Department restructured its pre-calculus curriculum. The Math 1 course was dropped altogether, and the Math 2A and Math 2B sequence was modified to include two courses, Math 2, College Algebra for Calculus and Math 3, Pre-Calculus. Previously the Math 2A/B sequence had been an alternative to Math 3. In order to take a calculus class, students must earn a score of 31 or higher on the Mathematics Placement Exam, or pass Math 3. Students scoring below 12 must take a Math class at a community college and re-take the Mathematics Placement Exam (scoring above 12) in order to enroll in a UCSC Math course. Students scoring between 12 and 19 enroll in Math 2 and students scoring between 20 and 30 enroll in Math 3. Course enrollment in Math 2 and Math 3 is quite large, from just under 200 to over 300 students per class each quarter.

Analysis of Students' Math Background Based on the Mathematics Placement Exam

The Mathematics Department uses the Mathematics Placement Examination as a means for several purposes. It is used as a means by which students' establish an initial placement into a mathematics course and is used to enable students to override their initial placement and proceed to higher level Mathematics courses. Since students are allowed to retake the exam, they also use it as a way to move between classes even if they have not passed the previous class. For example, a student who fails Math 2 but retakes the Mathematics Placement Exam and earns a score of 20 or higher may proceed to Math 3. This same student may retake the Exam again even if he/she fails Math 3 and if he/she earns a score of 31 will satisfy the math prerequisite for Psychology and Sociology majors and earn entrance to Math 11A, Calculus. A question worth investigating might be how many students move among math classes by retaking the

Mathematics Placement Examination rather than mastering the curriculum in a previous class?

As one of the purposes of this study is to investigate the relationship between students' performance on the Mathematics Placement Examination and their likelihood of passing the mathematics course into which they place, we will attempt to analyze the relationship of students' math preparation as measured by the MPE and the content and pacing of the course curriculum in Math 2 and Math 3.

In so far as it was possible to do so, Mathematics Placement Exam scores were collected for all of the students who enrolled in Math 2 or Math 3 in the fall of 2003 and who had taken the test just prior to enrolling in these courses. In other words, as far as we could tell, students had not enrolled in a math course between their test date and the first day of fall quarter. Table 1 presents the percent of students' correct answers in each of the curricular areas covered by the Mathematics Placement Exam based on the item analysis provided by the test designers.

Table 1
Analysis of students' curricular knowledge based on
Mathematics placement exam scores
Fall, 2003
Mathematics Placement Exam Fall 2003

Class	Math 2	Math 3-01	Math 3-02
# of Tests	122	182	196
MPE Average Score	16.4	26.6	24.4
Exponents and Radicals	18%	31%	26%
Functions	28%	54%	49%
Linear Equations and Inequalities, and Absolute Values	38%	61%	55%
Logarithmic and Exponential Functions	22%	38%	35%
Polynomials and Polynomial Functions	26%	46%	43%
Rational Expressions and their Graphs	28%	45%	43%
Trigonometry	21%	30%	31%
Word Problems	36%	50%	46%

Table 2 ranks the students' performance patterns in the order in which they found the concepts to be difficult, beginning with the most difficult areas and ending with the least difficult conceptual areas.

Table 2
Item Analysis of Student's Performance
On the Mathematics Placement Exam
Ranked by Level of Difficulty for Students

Math 2	Math 3	Math 3
Exponents and Radicals	Exponents and Radicals	Trigonometry
Trigonometry	Trigonometry	Exponents and Radicals
Logarithmic and Exponential Functions	Logarithmic and Exponential Functions	Logarithmic and Exponential Functions
Polynomials and Polynomial Functions	*Polynomials and Polynomial Functions	Rational Expressions and their Graphs
*Rational Expressions and their Graphs	*Rational Expressions and their Graphs	Polynomials and Polynomial Functions
*Functions	Word Problems	Word Problems
Word Problems	Functions	Functions
Linear Equations and Inequalities, and Absolute Values	Linear Equations and Inequalities, and Absolute Values	Linear Equations and Inequalities, and Absolute Values

* Equal ranking

The mean placement test scores of these student groups are approximately half-way between the entry and exit scores for Math 2 and Math 3 respectively. In both classes, the students' previous knowledge and skills from least mastered to most competent are similar with "Exponents and Radicals" being most problematic and "Linear Equations and Inequalities" being most facile. Although there is similarity in students' apparent domains of math knowledge, it is also obvious that the students entering Math 3 have a greater depth of knowledge than students entering Math 2. Although all of these students completed the high school UC Math requirements, the Math 2 students demonstrate limited math background by UC standards. Theoretically, then, Math 2 would need to bring its enrollees demonstrated mathematical ability/knowledge base up to the level necessary to enter and successfully complete Math 3. Therefore, let us examine the relationship of the information about students gleaned from this item analysis of their MPE scores and the curricula of Math 2 and Math 3. We will begin with an analysis of Math 2.

Analysis of the Relationship of Students Demonstrated Preparedness for Math 2 and the Focus of the Math 2 Curriculum

Table 3 presents an outline of the Math 2 curriculum.

Table 3
CURRICULUM OUTLINE
MATH 2

Concept	For the quarter	Before Midterm	After Midterm
Total # of lectures	25	11	14
Linear Equations and Inequalities, Absolute Values and their Graphs	26.0% (6.5)	45.5% (5)	10.7% (1.5)
Polynomials, including Quadratic Equations	18.0% (4.5)	18.2% (2)	17.9% (2.5)
Exponents and Radicals	16.0% (4)	9.1% (1)	21.4% (3)
Rational Expressions	16.0% (4)	0%	28.6% (4)
Geometrical Applications	8.0% (2)	0%	14.3% (2)
Review (Tips for success in Math, Algebraic Expressions, Sets of Numbers, Operations and Properties of Real Numbers)	4.0% (1)	9.1% (1)	0%
Functions	4.0% (1)	9.1% (1)	0%
Word Problems*	4.0% (1)	9.1% (1)	0%
Complex Numbers*	4.0% (1)	0%	7.1% (1)
Conceptual Geometry	0	0%	0%

** Numbers reported in parenthesis are the total number of lectures spent on each topic.

Table 4 presents a comparison of student's demonstrated curricular difficulties as represented by an item analysis of their performance on the Mathematics Placement Examination and the Math 2 curriculum. It must, however, be remembered that the Mathematics 2, College Algebra for Calculus, course is a class two levels below entrance to University Calculus.

Table 4
Math 2 Curriculum Analysis By
Areas of Difficulty on the
Mathematics Placement Exam

Math 2	MPE	Pre-Test #SR45A93	% Lectures
# of Tests	122	480	
Average Score (total possible score)	16.4 (60)	21.4 (45)	
Linear Equations and Inequalities, and Absolute Values	38%	49%	26.0% (6.5)
Word Problems	36%		4.0 %(1)
*Functions	28%		4.0% (1)
Rational Expressions and their Graphs	28%	50%	16.0% (4)
Polynomials and Polynomial Functions	26%	50%	18.0% (4.5)
*Logarithmic and Exponential Functions	22%		
Trigonometry	21%		
Exponents and Radicals	18%	48%	16.0% (4)
Graphical Representation		56%	
Conceptual Geometry		42%	
Geometrical Applications		41%	8.0% (2)
Complex Numbers			4.0% (1)
Review (tips for success in Math, Algebraic Expressions, sets of numbers, operations and properties of real numbers)			4.0% (1)

% For MPE and Pre-Tests are % of students who answered this type of question correctly
*Functions and Logarithmic and Exponential Functions are listed as one single category on the Pre-Test though they are tested separately on the Mathematics Placement Exam.

The initial review of algebraic expressions is not explicitly tested by the Mathematics Placement Exam, and complex numbers are also not an explicit area of assessment. However, it is evident that some of the concepts which Math 2 students found most challenging on the Mathematics Placement Exam are not being given much time during class. Examples include "Exponents and Radicals (16% of class lectures), "Trigonometry" and "Logarithmic and Exponential Functions." Although it could be argued that both Trigonometry and Logarithmic and Exponential Functions rightfully belong in the Math 3 curriculum, Math 2 students will then enter Math 3 at a lower level of competence in these areas than most of the students who enter Math 3 directly by placing into the class.

On the other hand, the breadth of conceptual material being covered in Math 2 is large. For students experiencing a ten-week quarter for the first time, transitioning from the slower pace of a high school semester, the pace of the course may be challenging. And, it is likely that, due to their apparent difficulty in such basic areas the course expectations may begin above the level of student's demonstrable prior knowledge.

The relationship of students' demonstrated preparedness for the current Math 2 curriculum and their likelihood of passing the course is further illustrated by Table 5. Although a few students with very low MPE scores did pass the Math 2 class, the trend supports our previous observation that students with low MPE scores within the range of Math 2 placement struggle to pass the class.

Table 5
Fall 2003 Math 2
Math Placement Exam (MPE) Score and the % of Students who passed the class with this score

MPE Score	# of Students with this Score	% Students who Passed the Class With this Score
10	2	100% (2)
11	0	N/A
12	4	50% (2)
13	9	44% (4)
14	13	77% (10)
15	12	92% (11)
16	11	82% (9)
17	16	75% (12)
18	15	80% (12)
19	6	67% (4)
Above 19	7	100% (7)

Fall 2003 Math 2
MPE Score and the % of students who passed the class with this score

MPE Score Range	# of Students in this Range	% Students who Passed the Class in this Range
10-16	51	75% (38)
Above 16	44	80% (35)
Class Average Score 16.3	95	77%(73)

As part of the process of determining how best to improve students' success in Math 2, a pre-test focused on basic college algebra skills is now given on the second day of instruction, and students are recommended into required sections of two or four hours per week based on their scores. Table 6 presents an analysis of students' conceptual understanding based on their pre-test scores.

Table 6
Math 2 Pre-Test Scores
Math 2 Test # SR45A93

Class	Winter 2004	Fall 2004	Winter 2005	Average
# of Tests	158	201	121	480
Pre-test Average Score	19.6	22.6	21.9	21.4
Rational Expressions	43%	53%	48%	48%
Linear Equations and Inequalities, Absolute Values and their Graphs	43%	52%	53%	49%
Exponents and Radicals	45%	53%	50%	50%
Polynomials, including Quadratic Equations	45%	54%	52%	50%
Functions, including Logarithmic and Exponential	52%	59%	56%	56%
Geometrical Applications	40%	41%	42%	41%
Conceptual Geometry	38%	45%	43%	42%

In all of the Math 2 classes thus far that have taken the pre-test, the two sections on geometry have proven to be most challenging. However, Geometric Applications is receiving 8% of lecture time; a small percentage, but perhaps adequate as students need only a basic understanding of geometry in preparation for Calculus. The next two areas of most difficulty were "Rational Expressions and Their Graphs" and "Linear Equations and Inequalities, Absolute Values and their Graphs." These topics now account for 42% of Math 2 instructional time.

This analysis of the students' prior knowledge and experience based on the MPE and the Math 2 Pre-test as compared with the Math 2 curriculum points to the lack of students' preparedness and the breadth of the material being covered. Based on the preceding data, it seems reasonable to ask; is it possible to bring Math 2 students to the level of mathematical competence for success in Math 3 in one quarter?

Analysis of Students Preparedness and the Curriculum focus for Math 3

Table 7 presents an overview of the curriculum and instructional pacing for Math 3.

Table 7
CURRICULUM OUTLINE
MATH 3

Concept	For the quarter	Before Midterm 1	Before Midterm 2	After Midterm 2
Total # of lectures	27	11	11	5
Trigonometry	44.4% (12)	0%	81.8% (9)	60% (3)
Logarithmic and Exponential Functions	31.5% (8.5)	68.2% (7.5)	9.1% (1)	0%
Geometrical Applications	7.4% (2)	9.1% (1)	9.1% (1)	0%
Sequences and Series	7.4% (2)	0%	0%	40% (2)
Polynomials and Polynomial Functions	5.6% (1.5)	13.6% (1.5)	0%	0%
Rational Expressions and their Graphs	3.7% (1)	9.1% (1)	0%	0%

*Numbers reported in parenthesis are the total number of lectures spent on each topic.

As with Math 2, students had the greatest difficulty with geometry-related problems. Yet, 7.4% of lecture time is spent on these concepts, and only basic knowledge of geometry is relevant to success in calculus. Students also experienced difficulty with Polynomials and Polynomial functions and Rational Expressions and their Graphs: concepts on which 9.3% of the course lectures are focused. Trigonometry which was not tested on the pre-test but which was rated very high in terms of students' difficulty on the MPE accounted for 44% of the class lecture time. As compared with Math 2, Math 3 covers fewer concepts in greater depth.

As with Math 2, a pre-test is now given on the second day of class in Math 3 course sections supported by Learning Support Services, wherein students are assigned to small 2 or 4 hour sections. Table 8 presents the pre-test scores for Math 3, and Table 9 presents a summary of students' skill-base from least to most difficult reflected by their Math Placement Exam and pre-test scores and the amount of instruction focused on each topic.

Table 8
Students' Pre-test Scores
Math 3
Math 3 Test # MR45A92

Class	Spring 2004	Fall 2004 Section 2	Winter 2005	Average
# of Tests	263	231	359	853
Pre-test Average Score	17.6	20.3	19.8	19
Rational Expressions	30%	35%	36%	34%
Exponents and Radicals	44%	49%	49%	47%
Linear Equations and Inequalities, Absolute Values and their Graphs	60%	69%	66%	65%
Polynomials, including Quadratic Equations	31%	32%	33%	32%
Functions, including Logarithmic and Exponential	44%	52%	49%	48%
Geometrical Applications	31%	40%	37%	36%
Conceptual Geometry	30%	33%	34%	32%

Table 9
Students' MPE and Pre-Test Scores Ranked by Difficulty and
As Related to Curricular/Instructional Time on Task

Math 3	MPE	Pre-Test #MR45A92	% Lectures
# of Tests	378	853	
Average Score (total possible score)	25 (60)	19 (45)	
Linear Equations and Inequalities, and Absolute Values	58%	65%	
*Functions	51%	66%	
Word Problems	48%		
Polynomials and Polynomial Functions	44%	32%	5.6% (1.5)
Rational Expressions and their Graphs	44%	34%	3.7 % (1)
*Logarithmic and Exponential Functions	36%	37%	31.5% (8.5)
Trigonometry	31%		44.4% (12)
Exponents and Radicals	28%	47%	
Geometrical Applications		36%	7.4% (2)
Conceptual Geometry		32%	
Sequences and Series			7.4% (2)

% For MPE and Pre-Tests are % of students who answered this type of question correctly
*Functions and Logarithmic and Exponential Functions are listed as one single category on the Pre-Test though they are tested separately on the Mathematics Placement Exam.

Overall, the analysis of the students' performance on both the MPE and the pre-tests now used in Math 2 and Math 3 reveal several issues. In general, the course curricula seem to

address student's skill development needs. Yet, it seems likely that students weak in certain skill areas may be being expected to begin to follow lectures and solve problems above their level of previous competence. Perhaps the curriculum begins at too high a level for many students who score below the mid-point of the entry range as determined by the MPE. Also, the breadth of the curriculum, especially in Math 2, may be very challenging for students with underdeveloped math skills, as the courses must move quickly through many conceptual areas. Perhaps the MPE score ranges for placing students into Math 2 and Math 3 need to be reconsidered. Additionally, certain instructional design factors may also need to be considered. In Math 2, there is one mid-term and a final exam. Traditionally, almost all of the students in Math 2 (often all but 15 or 20) pass the mid-term, while over 25% usually fail the final exam. Perhaps the pacing of the course should be altered. In Math 3 there are two mid-terms and a final exam. A cursory look at past course records seems to indicate that many students who fail the first mid-term pass the second one. Overall, however, it may be that the breadth of material covered in these courses is just too broad for those students who enter the class with the lowest pre-test and MPE scores to earn a passing grade in spite of the increased instructional support which Math and LSS have developed.

RESULTS OF THE REVISED SECTION CONFIGURATION FOR MATH 2 AND MATH 3

In the fall of 2003 Learning Support Services formed a partnership with the Mathematics Department in an attempt to increase students' success in the pre-calculus program by offering interactive instructional sections of from 10 to 15 students. We hypothesized that smaller sections focused on interactive problem solving would increase students' likelihood of achieving academic success in Math 2 and Math 3. An analysis of our data thus far supports the improvement of students' academic performance in Math 2 but is inconclusive regarding Math 3.

Analysis of Students' Academic Performance in Math 2, Fall 2002 – Fall 2004

Table 10 summarizes the course pass/no pass and withdrawal data from fall 2002 through fall, 2004. During this time, the support services model for Math 2 evolved. In fall, 2002 and winter 2003, Math 2 lectures were accompanied by 1 hour sections of approximately 30 students (recommended but not required). In the fall of 2003 we began the expanded support program for Math 2 by requiring each student to attend a one hour section each week of no more than 12 students. This model did not produce an increase in the pass rate; however, Math 2 traditionally has a higher pass rate in the fall than in the winter. At the suggestion of the professor, we implemented a different model in the winter of 2003. Students were given a pre-test on the second day of class. Based on these scores they were recommended to enroll in a 1 hour, 2 hour, or 4 hour section of 10 to 12 students. Compared with the pass rate for the previous fall and winter, this model appeared to contribute positively to students' academic performance. The pass rate was 1.5% higher than fall 2002 and 4.9% higher than winter, 2003. In the fall of 2004, the model was yet again modified wherein, based on their pre-test scores, students were recommended to enroll in required 2 or 4 hour sections. As is evident from the table, this model yielded the highest pass rate of the program thus far, 5.3% higher than fall 2002.

Table 10
Course Pass Rates
Math 2

	# of students in Class	Class pass rate	No Pass/W Rate	Withdraw Rate
Fall 2002	198	73.2%	26.8%	4.0%
Winter 2003	129	69.8%	30.2%	7.0%
Fall 2003	146	74.7%	25.3%	6.9%
Winter 2004	166	75.9%	24.1%	6.0%
Fall 2004	209	78.5%	21.5%	1.9%

Thus far, the model of using a pre-test to assess students' entry level algebra skills and requiring them to enroll in a small interactive two or four hour section focused on understanding Math concepts and developing problem solving skills has resulted in a 7.24% increase in the students' pass rate from fall, 2002 to fall, 2004, and an 8.74% increase from winter 2003 to winter 2004. Certainly, we had hoped for a larger increase, but the program does seem to be resulting in a positive educational outcome for some students.

Table 11 presents a breakdown of students' academic performance based on the section-type into which they enrolled. One of the observations which the professor of the class made, an observation which impressed and pleased him, was that the students who entered the class with under-developed Math skills (low score on the Pre-Test) and enrolled in the 4 hour sections passed the class at a higher rate than he had remembered in the past. These students, who entered the class with the least developed Math skills, did not have an overall pass rate much lower than that of the initially more prepared students. In fact, in winter 2004 the students enrolled in the four hour sections passed the class at a higher rate than any other group.

Data for each class is presented in two ways. First, the actual section enrollment pattern for the entire class is presented. Then, data is presented for those students who actually enrolled in the section into which they were recommended: a 1, 2, or 4 hour section.

Table 11
Pre-Test Scores, Section Assignments and Pass/No Pass Rates for Math 2
MATH 2
Whole Class

Winter 2004	# of Students	Pass Rate	No Pass/W Rate	W Rate
Whole class	165	75.8%	24.2%	6.1%
4 – hour sections	20	85.0%	15.0%	5.0%
2 – hour sections	55	72.7%	27.3%	9.1%
1 – hour sections	69	81.2%	18.8%	2.9%
Not enrolled in a section	21	51.7%	48.3%	9.5%

Students in Recommended Section

Winter 2004	Pre-Test Range	# of Students	Pass Rate	No Pass/W Rate	W Rate
4 – hour sections	5-13	14	78.6%	21.4%	7.1%
2 – hour sections	14-18	33	78.8%	21.2%	6.1%
1 – hour sections	19-39	53	81.1%	18.9%	3.8%

Fall 2004	# of Students	Pass Rate	No Pass/W Rate	W Rate
Whole class	209	78.5%	21.5%	1.9%
4 – hour sections	43	72.1%	27.9%	2.3%
2 – hour sections	156	80.8%	19.2%	1.9%
Not enrolled in a section	10	70.0%	30.0%	0.0%

Students in Recommended Section

Fall 2004	Pre-Test Range	# of Students	Pass Rate	No Pass/W Rate	W Rate
4 – hour sections	4-19	42	71.4%	28.6%	2.4%
2 – hour sections	20-40	115	84.3%	15.7%	0.9%

This table presents some interesting, but not unexpected, trends. As the pass rate of students who enrolled in the four-hour sections in the tables depicting whole class data is higher than the pass rate for students who enrolled in the four-hour sections as recommended, it seems that some initially more prepared students opted for the additional support of a four-hour section and benefited from this decision. However, in general, the students who enroll in the four-hour sections based on pre-test scores and instructor recommendation continue to pass the class at the lowest rate, between 71 and 78%. Students recommended to enroll in 2-hour sections performed slightly better, from 78% to 80%.

The important question raised by this data seems to be whether or not it is educationally appropriate to expect that students who enter Math 2 with low assessment scores on both the MPE and the algebra-oriented pre-test can master the course material in one quarter? Even with small, four-hour per week, interactive required sections almost one-fourth of these students fail the class. Is it necessary for the Mathematics Department to re-assess the viability of teaching these under prepared students the conceptual framework and problem-solving skills necessary for success in Math 3, pre-calculus, in one quarter?

An additional instructional resource available to students is Modified Supplemental Instruction. Table 12 compares the course performance trends for students who chose to attend MSI and students who did not choose to participate in this voluntary learning support program.

Table 12
Comparison of Course Performance Data for
Students Who Did and Did Not Participate in MSI

		Pass Rate without "W" Grade	Pass Rate with "W" Grade	No Pass Rate without "W" Grade	No Pass Rate with "W' Grade	"W" Rate
Fall 2002	MSI	81.3%	80.2%	18.7%	19.8%	1.2%
	Non-MSI	72.7%	68.4%	27.3%	31.6%	6.0%
	Whole class	**76.3%**	**73.2%**	**23.7%**	**26.8%**	**4.0%**
Winter 2003	MSI	80.0%	75.0%	20.0%	25.0%	6.3%
	Non-MSI	72.0%	66.7%	28.0%	33.3%	7.4%
	Whole class	**75.0%**	**69.8%**	**25.0%**	**30.2%**	**7.0%**
*Fall 2003	MSI	84.4%	78.6%	15.6%	21.4%	6.8%
	Non-MSI	70.0%	65.1%	30.0%	34.9%	7.0%
	Whole class	**80.1%**	**74.7%**	**19.9%**	**25.3%**	**6.8%**
*Winter 2004	MSI	83.3%	79.4%	16.7%	20.6%	4.8%
	Non-MSI	80.2%	74.8%	19.8%	25.2%	6.8%
	Whole class	**81.4%**	**76.5%**	**18.6%**	**23.5%**	**6.0%**
*Fall 2004	MSI	82.3%	80.2%	17.7%	19.8%	2.6%
	Non-MSI	77.2%	76.3%	22.8%	23.7%	1.1%
	Whole class	**80.0%**	**78.5%**	**20.0%**	**21.5%**	**1.9%**

* = Math 2 course sections supported by the small sections/MSI Model

Students who attended MSI had a higher pass rate and a lower W rate (except for the W rate in fall, 2004). However, only 53% of the enrolled students each quarter chose to participate in an MSI group. Learning Support services and the Mathematics Department have not been successful in convincing students who are in danger of failing the class to use MSI as an educational resource.

An examination of students' pre-test results further illustrates the difficulties which students with under-developed Mathematical understanding experience in Math 2. Table 13 presents a summary of the relationship between students' pre-test scores and course pass/no pass data.

Table 13
Fall 2003 Math 2
Pre-Test Score and the % of Students who Passed the Class with this Score
Test # MR45A92

Pre-Test Score Range	# of Students in this Range	% Students who Passed the Class in this Range
4-12	66	62% (41)
13-25	67	87% (58)
Class Average Score 12.4	133	74%(99)

Winter 2004 Math 2
Pre-Test Score and the % of Students who Passed the Class with this Score
Test # SR45A93

Pre-Test Score Range	# of Students in this Range	% Students who Passed the Class in this Range
5-19	77	79.2% (61)
20-39	65	80.0% (52)
Class Average Score 19.7	142	79.6% (113)

Fall 2004 Math 2
Pre-Test Score and the % of Students who Passed the Class with this Score
Test # SR45A93

Pre-Test Score Range	# of Students in this Range	% Students who Passed the Class in this Range
4-22	107	72% (77)
23-40	85	87% (74)
Class Average Score 22.4	192	79% (151)

(See Appendix 1 for a presentation of the relationship between each pre-test score and students' course pass rates.)

The Math 2 pre-test score data continues to reveal the difficulties which under prepared students are experiencing in Math 2. The average pass rate for students scoring below the class mean on the pre-test, even with an opportunity to enroll in a four-hour section, is 72%. Although during the Winter of 2004, the pass rate was somewhat higher, 79%. Overall it appears that, even with four-hour sections each week where section attendance is mandatory and interactive problem solving sessions are provided, approximately 25% of students who place below the class mean on the pre-test do not pass the class. Yet, these students did fulfill the Math requirements for UC admission, and may need to demonstrate competence at the pre-calculus level in order to pursue the majors of their choice and/or to pass a Quantitative (Q) class as part of their General Education Requirements.

During the first quarter of the partnership between LSS and the Mathematics Department, we gave both a pre and a post test in Math 2. The test given at both the beginning and end of the class was similar in scope to the MPE. Table 14 summarizes students' assessment results.

Table 14
Math 2 Pre and Post-Test Results
Fall, 2003
Test # MR45A92

Class	Fall 2003 Math 2 Pre-Test	Fall 2003 Math 2 Post-Test	Average From Math 3 Pre-Tests
# of Tests	139	147	853
Pre-test Average Score	12.4	19.7	19
Rational Expressions	16%	34%	34%
Exponents and Radicals	29%	52%	47%
Linear Equations and Inequalities, Absolute Values and their Graphs	43%	63%	65%
Polynomials, including Quadratic Equations	18%	45%	32%
Functions, including Logarithmic and Exponential	30%	49%	48%
Geometrical Applications	24%	32%	36%
Conceptual Geometry	29%	27%	32%

The Post-Test used in Math 2 was the same as the Pre-Test which the Math 3 instructors administer on the second day of class. This data is interesting because it appears that in most areas the students exiting Math 2 earned an average score the same or very similar to the students entering Math 3. This data leads to an important question: do students who placed directly into Math 3 indicating that they come to UCSC with more demonstrated previous math understanding have different levels of academic success than students who enter Math 3 having completed and passed Math 2? This Post-Test data indicates that the Math 2 students would be equally prepared for Math 3, yet course pass/no pass data indicates that Math 3 students who take the class in winter and spring quarters (perhaps after taking Math 2) experience a higher failure rate. More data collection and analysis are needed.

Discussion of Grade Distribution Data in Math 2

As mentioned before, the Math 2 professor believes that the recommended two and four-hour small, interactive sections have resulted in enabling the lowest-skilled students to earn grades across the A-F continuum. His recollection is that, in the past, these students tended to clump together at the bottom of the class grade range. Appendix 2 presents graphs of the grade distribution data by section type for Math 2, winter 2004 and fall, 2004. In winter, 2004, the students enrolled in four-hour sections earned fewer D and F grades than their peers, however, this was not the case in fall, 2004. In winter 2004, the

students who enrolled in four-hour sections as recommended earned more C/C+ and A grades than students in the two-hour sections. In the fall of 2004, the four-hour section recommended students earned an equal number of C grades as their peers, and within 12% as many B grades. Yet, they did receive more non-passing grades than any other group.

This grade distribution data does offer encouraging support for the trend toward a higher pass rate in Math 2. Yet a group of approximately 25% of the students is still unable to demonstrate mastery of the material.

Analysis of Students' Academic Performance in Math 3, spring and fall, 2004

It was not until the spring of 2004 that we implemented the small course section/MSI model in Math 3, although we had supported Math 3 with MSI for several years. However, as the Math 3 curriculum underwent revision when the entire pre-calculus curriculum was revised, all Math 3 comparative data presented here will go no further back than the fall of 2002.

Table 15 presents an overview of the course pass/no/pass/w data from fall, 2002 through fall, 2004. Table 16 presents a comparison of course pass rates for students who chose to attend MSI and students who did not choose to participate in the program.

Table 15
Course Pass Rates
Math 3

	# of students in Class	Class pass rate	No Pass/W Rate	Withdraw Rate
Fall 2002 Section 1	252	97.2%	2.8%	1.6%
Fall 2002 Section 2	255	83.9%	16.1%	7.1%
Winter 2003	278	97.5%	2.5%	1.4%
Spring 2003	224	63.8%	36.2%	19.2%
Fall 2003 Section 1	251	76.1%	23.9%	15.1%
Fall 2003 Section 2	308	76.3%	23.7%	8.4%
Winter 2004	282	76.2%	23.8%	9.9%
Spring 2004*	267	51.7%	48.3%	17.2%
Fall 2004 Section 1	206	84.0%	16.0%	2.4%
Fall 2004* Section 2	239	82.0%	18.0%	2.1%

Table 16
Comparative Data
MSI and Non MSI Attendees

		Pass Rate without "W" Grade	Pass Rate with "W" Grade	No Pass Rate without "W" Grade	No Pass Rate with "W' Grade	"W" Rate
Fall 2002 Section 1	MSI	100.0%	100.0%	0.0%	0.0%	0.0%
	Non-MSI	98.7%	97.1%	1.3%	2.9%	1.7%
	Whole class	**98.8%**	**97.2%**	**1.2%**	**2.8%**	**1.6%**
Fall 2002 Section 2	MSI	93.3%	93.3%	6.7%	6.7%	0%
	Non-MSI	90.1%	83.3%	9.9%	16.7%	7.5%
	Whole class	**90.3%**	**83.9%**	**9.7%**	**16.1%**	**7.1%**
Winter 2003	MSI	***	***	***	***	***
	Non-MSI	***	***	***	***	***
	Whole class	***	**97.5%**	***	**2.5%**	**1.4%**
Spring 2003	MSI	83.3%	73.5%	16.7%	26.5%	11.8%
	Non-MSI	74.7%	55.7%	25.3%	44.3%	25.4%
	Whole class	**79.0**%	**63.8**%	**21.0**%	**36.2**%	**19.2**%
Fall 2003 Section 1	MSI	94.6%	88.3%	5.4%	11.7%	6.7%
	Non-MSI	87.9%	72.3%	12.1%	27.7%	17.8%
	Whole class	**89.7%**	**76.1%**	**10.3%**	**23.9%**	**15.1%**
Fall 2003 Section 2	MSI	85.7%	84.0%	14.3%	16.0%	2.0%
	Non-MSI	82.8%	74.8%	17.2%	25.2%	9.7%
	Whole class	**83.3%**	**76.3%**	**16.7%**	**23.7%**	**8.4%**
Winter 2004	MSI	85.4%	76.9%	14.6%	23.1%	9.9%
	Non-MSI	84.3%	75.9%	15.7%	24.1%	9.9%
	Whole class	**84.6%**	**76.2%**	**15.4%**	**23.8%**	**9.9%**
*Spring 2004	MSI	70.4%	63.3%	29.6%	36.7%	10.2%
	Non-MSI	53.8%	41.0%	46.2%	59.0%	23.7%
	Whole class	**62.4**%	**51.7**%	**37.6**%	**48.3**%	**17.2**%
Fall 2004 Section 1	MSI	89.7%	89.7%	10.3%	10.3%	0.0%
	Non-MSI	85.5%	83.1%	16.9%	14.5%	2.8%
	Whole class	**86.1%**	**84.0%**	**16.0%**	**13.9%**	**2.4%**
Fall 2004 Section 2	MSI	85.2%	83.1%	14.8%	16.9%	2.4%
	Non-MSI	83.0%	81.4%	17.0%	18.6%	1.9%
	Whole class	**83.8%**	**82.0%**	**16.2%**	**18.0%**	**2.1%**

* = Math 3 course sections supported by the small sections/MSI Model
*** = This data was not collected

A perusal of the pass no/pass data and MSI attendance indicates two important trends. First, students who choose to attend MSI pass the class at a higher rate than students who do not attend MSI. Second, the overall academic performance of students' in Math 3 fluctuates noticeably from quarter to quarter. These performance differences may be affected by differences among instructors and by the higher proportion of students in

winter and spring who are likely to have enrolled in Math 3 after completing Math 2, rather than entering Math 3 with solid, pre-college preparation. In any case, due to the fact that several faculty members teach Math 3 and that the more intensive support for Math 3 offered by Learning Support Services and the Mathematics Department has only been available since spring, 2004, it is much more difficult to appropriately analyze its instructional effects.

Based on our instructional support experiences in Math 2, the planning team of Mathematics faculty members and Learning Support Services staff decided to implement the Math 2 instructional model which had been most effective as we began to modify the section structure in Math 3. Therefore, in the spring and fall of 2004 and the winter of 2005 all students in designated sections of Math 3 were given a pre-test and recommended to enroll in either a 2 or a 4 hour section. Section attendance was required. Students' performance data from these Math 3 classes is interesting and raises several, yet to be answered, questions.

We will begin with a discussion of the course performance data for Math 3 excluding the data for spring, 2004. This data must be analyzed separately, as an undetected error in the Mathematics Department scoring of the pre-tests made the recommended section assignments incorrect. In fact, 63% of the students were incorrectly recommended to sections. Table 15 (page 16) presents student's course pass rates.

It appears that the pass rate in Math 3 decreased as of the fall of 2003, but began to rebound in the fall of 2004. There also seems to be a consistent decrease in the Math 3 pass rate as an academic year progresses, with the fall pass rate being the highest and the spring pass rate being the lowest. In the fall of 2004, Section 2 of Math 3 was the class to which the required small sections were attached, and students in that class had a slightly lower overall pass rate than students in Math 3 section 1. It is noteworthy that the ACE program supported students from both sections of the class. 7 students in Math 3-01 and 33 students from Math 3-02 were enrolled in ACE sections. The winter, 2005 Math 3 class was supported by small required sections, and the course pass rate was 4% higher than in winter, 2004. However, the two sections were not taught by the same instructor, so teacher effect could account for the difference. Thus far, what we can say is that there is little or no evidence that the model of pre-testing students and assigning them to two or four-hour, small (10 to 12 students) sections results in improved course performance. On the other hand, the pass rates in the fall and winter of 2004-05 did improve. A closer look at the data is obviously necessary.

Table 17 presents the student pass rates by section type. We would anticipate that students with lower pre-test scores might experience more difficulty in the class than students with higher pre-test scores, but we would hope that the four-hour, small sections might mitigate some of that difference, (The data for spring, 2004, is only for those students who were correctly placed into sections based on their pre-test scores).

Table 17
Math 3
Students' Pass Rate by Section Type

Students in Recommended Section

Spring 2004	Pre-Test Range	# of Students	Pass Rate	No Pass/W Rate	W Rate
4 – hour sections	6-14	24	50.0%	50.0%	12.5%
2 – hour sections	15-20	46	41.3%	58.7%	21.7%
1 – hour sections	21-32	34	58.8%	41.2%	14.7%

Fall 2004 Math 3 Section 2	# of Students	Pass Rate	No Pass/W Rate	W Rate
Whole class	239	82.0%	18.0%	2.1%
4 – hour sections	53	77.4%	22.6%	3.8%
2 – hour sections	141	81.6%	18.4%	1.4%
ACE	33	93.9%	6.1%	3.0%
Not in a section	12	75.0%	25.0%	0.0%

Students in Recommended Section

Fall 2004 Math 3 Section 2	Pre-Test Range	# of Students	Pass Rate	No Pass/W Rate	W Rate
4 – hour sections	7-19	50	76.0%	24.0%	4.0%
2 – hour sections	21-34	89	89.9%	10.1%	1.1%

This data is difficult to analyze based on the difficulty which the entire class experienced in Math 3 in the spring of 2004. Yet, in fall, 2004, as with Math 2, students recommended to enroll in the four-hour sections based on their pre-test scores had the lowest pass rate. It is also noteworthy that the students enrolled in the ACE program passed the class at the highest rate. The quality of the ACE program is, of course, a contributor to these students' success. However, the fact that ACE students are generally interested in majoring in Science and Engineering rather than areas in the social sciences may also be a contributing factor. Also, the ACE sections are taught by skilled professionals rather than undergraduate learning assistants and graduate student teaching assistants.

Table 18 presents a sample of students' Pre-Test score and course performance data for Math 3-02, fall, and Math 3 in spring 2004.

Table 18
Fall 2004 Math 3-02
Pre-Test Score and the % of Students who Passed the Class with this Score
Test # MR45A92

Pre-Test Score Range	# of Students in this Range	% Students who Passed the Class in this Range
7 to 20	111	74% (82)
21 to 34	104	90% (94)
Class Average Score 20.3	215	83% (176)

(See Appendix 3 for a presentation of the relationship between each pre-test score and students' course pass rates.)

Although unintentional, the basically random placement of students in either 1, 2, or 4 hour Math 3 sections in the spring of 2004 produced some interesting course achievement patterns. Table 19 illustrates the relationship between students' Pre-Test scores (when the tests were rescored correctly) and their class pass rates. However, it must be remembered that students were not recommended to sections based on their accurate pre-test scores.

Table 19
Spring 2004 Math 3
Pre-Test Score and the % of Students who Passed the Class with this Score
Test # MR45A92

Pre-Test Score Range	# of Students in this Range	% Students who Passed the Class in this Range
5-17	129	42% (54)
18-32	114	63% (72)
Class Average Score 17.6	243	52% (126)

As with Math 2, students entering the class with demonstrated Math skills below the class mean pass the class at a lower rate. Again, it seems important to ask whether or not the amount of material covered in Math 3 and the commensurate instructional pace makes mastery of the material insurmountable for many of these students?

We will now examine the data from the accidental scoring error which resulted in students being recommended randomly to Math 3 sections in the spring of 2004. Table 20 presents data for students who were inappropriately placed in to section.

Table 20
MATH 3
Whole Class

Spring 2004	# of Students	Pass Rate	No Pass/W Rate	W Rate
Whole class	267	51.7%	48.3%	17.5%
4 – hour sections	48	52.1%	47.9%	25.0%
2 – hour sections	121	53.7 %	46.3%	14.0%
1 – hour sections	88	50.0%	50.0%	18.2%

Students in Less Section than Recommended

Spring 2004	# of Students	Pass Rate	No Pass/W Rate	W Rate
Whole class	267	51.7%	48.3%	17.5%
2 – hour sections Recommended 4 Hour	35	25.7%	74.3%	22.9%
1 – hour sections Recommended 2 Hour	31	22.9%	77.1%	19.4%
1 – hour sections Recommended 4 Hour	12	41.7%	58.3%	16.7%

Students in More Section than Recommended

Spring 2004	# of Students	Pass Rate	No Pass/W Rate	W Rate
Whole class	267	51.7%	48.3%	17.5%
4 – hour sections Recommended 2 or 1 Hour*	20	80.0%	20.0%	5.0%
2 – hour sections Recommended 1 Hour	33	72.7%	27.3%	12.1%

*Only 2 people were recommended to 1 hour section and actually took 4 hours of Section (both received C Grades)

It is clear that students who enrolled in sections which met more hours than their recommended sections passed the class at a higher rate than the class totals, whereas, students who enrolled in fewer section hours than would have been recommended passed the course at a lower rate than their correctly placed peers. This data would have been expected based on our experience in Math 2 and in Math 3 in fall, 2004. Not only did

this incorrect section placement probably affect students' exposure to practice with math conceptual and problem-solving skills, it undoubtedly affected their self perceptions regarding their mathematical abilities. We regret the negative effects which this scoring and placement error may have had on students.

Analysis of Grade Distribution Data for Math 3

We will begin our analysis of grade distribution data by considering students' grades in Math 3-02, fall, 2004. Students in this class were correctly recommended into sections based on their pre-test scores. See appendix 4 for graphs presenting grade distribution by section.

Students recommended into four-hour sections earned more D and F grades than those recommended into 2 hour sections. They also earned more C and C+ grades. However, as was the case in Math 2, these initially lower-skilled students also earned A and B grades, again supporting the possibility that the expanded learning support available to these initially less prepared students may result in some of them "beating the odds" so to speak and demonstrating high levels of mastery of the course material.

Now, we will review the grade distribution data for Math 3 in spring, 2004 (the course where section placement was unintentionally random.) Appendix 5 contains 4 figures that illustrate the grade distribution for students who attended more hours and fewer hours of sections than would have been recommended. The grade distribution was higher for students who attended more section hours than would have been recommended had the pre-test been scored correctly. Of the students whose section recommendation was appropriate, the four hour sections earned more A, A-, and B+ grades than other students. However, their D and no-pass rates were also the highest of the 3 groups. Again, some of the least prepared students at the beginning of the class seem to spread themselves out along the grading scale, rather than falling to the lower end as would probably be expected, but one-fourth or more of these students did not pass the class.

SUMMARY OF DATA ANALYSIS

An overall analysis of the course performance data shows a steady increase in students' performance in Math 2 which might indicate that the small two and four hour sections are improving students' overall course performance. In Math 3, however, no clear trend is yet visible. We have no evidence that the small two and four hour sections are changing the overall students' course performance statistics. On the other hand, we also have no evidence that the program is detrimental. Our analysis of the data, however, indicates that the Learning Support Services/Math Department time commitment and costly support of Math 3 courses with small two and four hour sections may not be worth the investment. The traditional MSI support may be an equally effective alternative.

More importantly, however, the analysis of this data raises questions for this University to consider regarding the most ethical and educationally effective programs and services which should be provided for UC-admitted students who enter with underdeveloped mathematical understanding and inadequate demonstrable quantitative problem-solving

skills. Is it morally or educationally appropriate to effectively bar these students from all of the majors in Physical and Biological Sciences, Engineering and Computer Science, Sociology, Psychology, and Economics because they can not pass Math 2 and Math 3, a comprehensive, fast paced, 2 quarter pre-calculus sequence. Despite efforts to increase students' access to learning support, the no-pass rate in these courses consistently remains at 20 to 25%.

ANALYSIS OF PRE-CALCULUS AS A GATE KEEPER

In order to get a sense of how the pre-calculus requirement affects students' overall academic performance and eventual entry into a major, we randomly selected a small sample of students from the Math 2 course in winter 2004. We selected this Math 2 class because we feel that the model of small, required, two and four hour sections offered the best support to students of the instructional support models which we have tried thus far. Appendix 6 presents individual data for 13 students, four pre-psych, two CE/CS, 4 Pre-Biology and 3 economics majors. The students' achievement data reveals interesting patterns. Three of the four Psychology majors had SAT1 Math scores between 460 and 470. (One student's score was unavailable.) Three of the students passed Math 2 (winter, 2004) with a "C" and one student failed, but took Math 2 again and earned a "B". In their first attempt at Math 3, the students received an F, a W, and a NP. The student who received a NP retook the course and earned a C+. Yet, all of the students received B- or above in Psychology classes. One of the CE/CS majors earned a C in Math 2, failed Math 3, but retook it and earned a C, and changed majors from CE/CS to Psychology. The other CE/CS major earned an A- in Math 2, a C in Math 3, but had difficulty in CS12A earning a D on the first attempt and Math 19A, also earning a D on the first attempt. These students had Math SAT 1 scores of 450 and 430 respectively, but found Math and CE/CS challenging. The four Biology majors seemed to find pre-calculus courses less challenging. Three of the four students earned B-level grades in Math 2 and C-level grades in Math 3. And they received C and above in their lower division science classes. The one Biology major who failed Math 2 took no more math and declared a Community Studies major. The three Economics majors all completed Math 2 with passing grades (one C and 2 Bs). However, of the three, one failed Math 3 and failed AMS 11A, one has never enrolled in another math course, and one is currently enrolled in Math 3. The students' grades in economics classes were fair/good, except for one F in Economics 1, earned by a student who passed Math 2. It is not possible to generalize from such a small sample, but, for these students, pre-calculus math courses were most problematic for the Psychology and CE/CS interested students. Certainly, this data points to the necessity to recognize the importance of Math 2 and Math 3 to UCSC students as these courses are certainly gatekeepers. Further data analysis of students' by major is needed to determine whether or not the curriculum in Math 3 is, indeed, appropriate and necessary for students success in the majors which require completion of the course. It might be that, although some mathematical understanding is needed in each case, a better fit between the quantitative demands of each major and a more specifically designed Mathematics course would be advantageous to both students and academic departments.

LEARNING ASSISTANT TRAINING

The Math Department provides graduate student Teaching Assistants for Math 2 and Math 3 courses, but they can not, of course, offer two and four hour sections of from 10 to 12 students to accommodate courses with student enrollments from two to three hundred. Therefore, we hire and train undergraduate students to lead many of the sections. During the first quarter that they work in the program, the undergraduate Learning Assistants are required to enroll in a 2-unit course developed by Frank Bauerle, Ed Migliore, Sue Tappero, Gayle Alvarado and Holly Cordova. The purpose of this course is to provide systematic formal training in instructional strategies and a review of the Mathematical concepts covered in Math 2 and Math 3 for the Learning Assistants leading required discussion sections and voluntary MSI groups. The course focuses on assisting students to facilitate interactive group learning while ensuring that students master course concepts through problem solving activities. (See appendix 7 for the course syllabus, copies of the major assignments, and course handouts.) Students meet weekly in sessions focused on the following topics:

Role and responsibilities of Math 2 and Math 3 Learning Assistants
Group management techniques
Leading interactive group problem solving
Effective blackboard techniques
Teaching students how to use math textbooks
Techniques for developing quizzes
Assessing students' learning
Theory and practice of grading math exams
Developing and implementing exam review sessions
Recognizing and assisting students experiencing math anxiety and/or test anxiety
Developing questioning and listening skills
Strategies for developing interactive final exam review sessions.

Students completed 4 major assignments:

Assignment 1 – Weekly Quiz Design and Evaluation
Assignment 2 – Teaching demonstration
Assignment 3 – Observation and Analysis of a Peer-Guided Learning Session
Assignment 4 - Position Paper on One Aspect of Math Education

The course sessions were interactive with students practicing instructional techniques as they increased their understanding of the relationship of important math concepts and problem solving strategies.

We are very concerned that the undergraduate Learning Assistants are well trained and continually engaged in the course content. All Learning Assistants are required to attend each course lecture. Once they have completed the required training course, in subsequent quarters they must attend ten hours of Learning Support Services tutor training activities, as well as attending the TA meetings with the graduate Teaching Assistants and the professor. It has come to our attention that, in several cases, the small sections run by graduate student Teaching Assistants have apparently been most effective as measured by students' course achievement data. However, it is unlikely that we could

hire enough graduate student Teaching Assistants to staff approximately 17 2 and 4 hour sections (1/3 4-hour sections). Therefore, we must rely on a group of carefully trained undergraduate Learning Assistants.

The evaluations of the training course were very positive. It is not surprising that the Learning Assistants preferred the discussions and teaching-related assignments over the final paper writing requirement. However, their papers reflected important thinking regarding ways to increase the effectiveness of math education.

OVERVIEW OF HIGH SCHOOL MATHEMATICS AND ITS POSSIBLE RELATIONSHIP TO STUDENTS' STRUGGLES IN MATH 2 AND MATH 3

The essence of the lack of apparent preparation which UC-admitted students demonstrate on the MPE resulting in their enrollment in Math 2 and then in Math 3 seems to be related to their K-12 mathematics curricular exposure and instructional experiences. Yet, a perusal of the UC articulated high school curricula and the State of California Mathematics Content Standards indicates that the problem must be around issues of assessment and evaluation of students' mastery of the material rather than issues of students' exposure to mathematical concepts and practical problems.

All UC-admitted students must have taken and passed three years of course-work in high school mathematics, traditionally Algebra, Geometry, and Algebra 2 (sometimes called Algebra 2, Trigonometry). If students attend a high school which still uses the Integrated Mathematics Program, the concepts and skills contained in the traditional 3-course sequence are theoretically included in the 3-year Integrated Mathematics Program. Although there is some variation in textbooks (the State of California has approved a limited number of texts available in the public schools), each high school must participate in a curricular articulation process to ensure that UC will accept its Math courses as satisfying the Mathematics segment of the A-G eligibility requirements.

So, at least on paper, students are being exposed to the required algebraic and geometric concepts necessary for entrance to university-level math courses. Unfortunately, however, the reality of educational opportunities in California high schools is disparate. Each California high school is given a ranking on a six point scale based on its economic resources and apparent instructional effectiveness as measured by students' assessment test scores. Although students in Low-Performing high schools may have earned high grades in college preparatory mathematics classes, the quality of the instruction available to them will generally not be equal to that offered by the High-Performing schools. They may be exposed to similar textbooks, but they may not be engaged in conceptual and practical problem solving experience. Their classes may be overcrowded, their teachers may be inadequately trained, and they may not have exposure to the hands on materials and technology which can make math more exciting and more understandable.

Another significant difference between high school and university mathematics classes is the typical instructional strategies. For the most part, high school students experience math in classes of 30 students which meet daily. During some of the instructional time, students are divided into small groups and engage in problem-solving tasks. Instructors

do not tend to lecture for an hour or more at a time. Rather, they explain a concept and then set students to work on problems. Conceptual explanations and problem-solving practice are integrated in a small class setting where the teacher can easily ascertain students' levels of understanding. Obviously, incoming UCSC students are not prepared for the large Math lectures of over 200 students wherein the instructor rapidly presents concepts and works out exemplary problems. Students are then sent off to do homework on their own. Rather than the weekly quizzes and frequent tests common in high school, university students have one or two mid-terms and a comprehensive final examination.

University preparatory mathematics education is certainly problematic, as is UCSC math education at the pre-calculus level. Probably based on the poor quality of Low-Performing high schools and the significant difference between the instructional strategies used in high school and university mathematics courses, students who succeeded in their university-required high school math courses and legitimately earned admission to UCSC find themselves unable to meet the pre-calculus mathematics requirements of their chosen majors. In fairness to students, how can UCSC best alleviate this mismatch between students' preparation and UCSC expectations?

CONCLUSION

Several salient conjectures have arisen from this analysis of a two-year partnership between the Mathematics Department and Learning Support Services aimed at increasing students' success in Math 2 and Math 3 course. And, several important questions have emerged which deserve discussion throughout the university community. The faculty involved in this project contend that large lecture classes are not the optimal instructional delivery format within which to teach math to students whose mathematical understanding is beneath that expected by university-level mathematics courses. In theory at least, all of the students in Math 2 have already been exposed to the course content and have demonstrated mastery of it in order to pass high school courses. Yet, these students have not retained an understanding of the algebraic and geometric knowledge necessary for entrance into pre-calculus. The instructional staff participating in this gant project recommends that smaller classes would be of benefit to students. It was further suggested that these smaller classes could be adjusted to address different applications of the material. Although the conceptual material would remain constant, it could be exemplified with practical applications in different course sections: math for Psychology, Sociology, Economics, Biological and Physical Sciences, Computer Science, and Engineering majors. It is very possible that the general pre-calculus curriculum is not necessary or optimal as quantitative, skill-building preparation for all of the majors currently requiring students to pass Math 3.

Besides recommending small classes graduate student Teaching Assistants and undergraduate Learning Assistants commented that, for many students, the Math 2 and Math 3 courses are too broad. Perhaps the curriculum for each course should be offered in a two-quarter sequence for students whose MPE and/or pre-test scores are below the group mean. Certainly, students who are apt to struggle in the class should accept our advice and attend four-hour sections and participate in MSI groups.

Whenever possible, Graduate Student Teaching Assistants should be hired and trained to lead the four-hour sections, as their depth of mathematical knowledge should enable them to explain concepts and guide students through problem solving tasks more effectively than undergraduate Learning Assistants. Undergraduate Learning Assistants should be upper-division students who have demonstrated excellence in UCSC mathematics courses through calculus. And, it is important that we continue to require these undergraduate students to participate in a training course and ongoing training activities.

All of this being said, the most important outcome of this analytic study are the questions which it raises regarding the responsibility of UCSC to meet the instructional needs of its undergraduate students. Is it educationally appropriate for students who have satisfied the Admissions requirements by earning at least a passing grade, but most probably an A or B grade in three years of high school, college preparatory mathematics class to be denied entrance into a major field because they can not pass Math 2 and/or Math 3? Are students coming from under-resourced K-12 schools being again disadvantaged by UCSC's instructional packaging of math material below the calculus level? Certainly, not all students study appropriately and seriously address the challenges of the courses in which they enroll. Yet, as Math 2 and Math 3 have become insurmountable obstacles for approximately 20% of the enrollees each quarter, it appears that the university community might need to restructure the basic mathematics options available to students. Don't we have a responsibility to facilitate the academic achievement of the student admitted to UCSC all of whom are among the top 12.5% of California high school graduates? It is our hope that this report will be a catalyst for university-wide discussion of students quantitative instructional needs.

Appendix 1: Math 2 Pre-Test Scores and Pass Rates

Fall 2003 Math 2
Pre-Test Score and the % of Students who Passes the Class with this Score
Test # MR45A92

Pre-Test Score	# of Students with this Score	% Students who Passed the Class With this Score
4	3	33% (1)
5	1	0% (0)
6	1	0% (0)
7	8	38% (3)
8	11	91% (10)
9	11	73% (8)
10	12	58% (7)
11	9	67% (6)
12	10	60% (6)
13	13	92% (12)
14	15	87% (13)
15	12	75% (9)
16	8	100% (8)
17	6	83% (5)
18	6	100% (6)
19	3	67% (2)
21	3	67% (2)
25	1	100% (1)

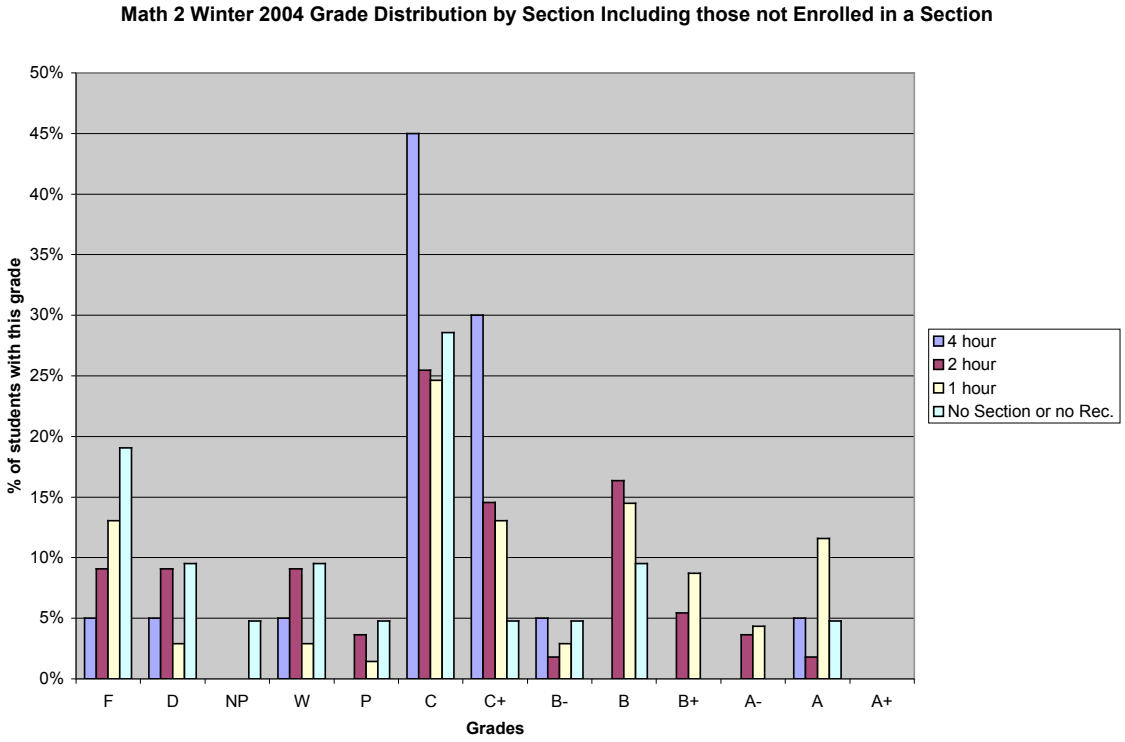
Fall 2004 Math 2
Pre-Test Score and the % of Students who Passes the Class with this Score
Test #

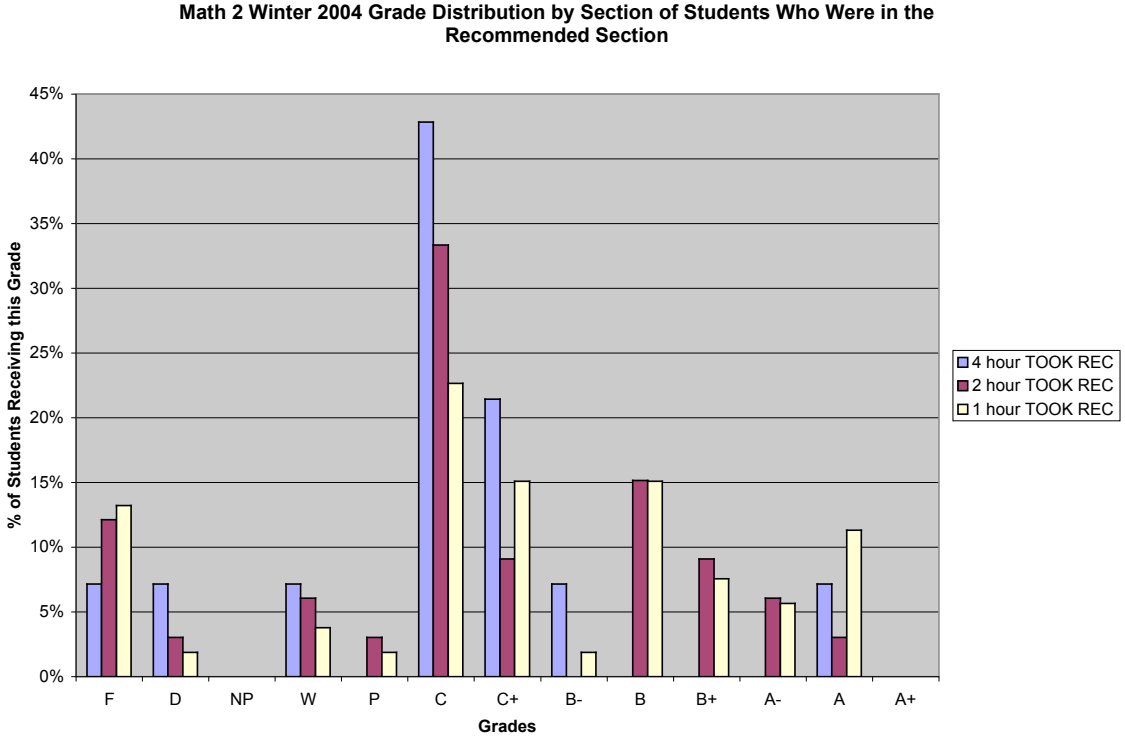
Pre-Test Score	# of Students with this Score	% Students who Passed the Class With this Score
4	1	0% (0)
8	1	100% (1)
9	1	100% (1)
10	2	0% (0)
11	2	50% (1)
12	2	100% (2)
13	8	63% (5)
14	4	100% (4)
15	3	33% (1)
16	12	58% (7)
17	9	78% (7)
18	10	70% (7)
19	18	83% (15)
20	11	82% (9)
21	11	73% (8)
22	12	75% (9)
23	8	75% (6)
24	7	86% (6)
25	7	86% (6)
26	11	91% (10)
27	8	75% (6)
28	5	60% (3)
29	10	80% (8)
30	6	100% (6)
31	5	100% (5)
32	2	100% (2)
33	3	100% (3)
34	3	100% (3)
35	2	100% (1)
36	1	100% (1)
37	4	100% (1)
38	1	100% (1)
39	1	100% (1)
40	1	100% (1)

Winter 2004 Math 2
Pre-Test Score and the % of Students who Passes the Class with this Score
Test #

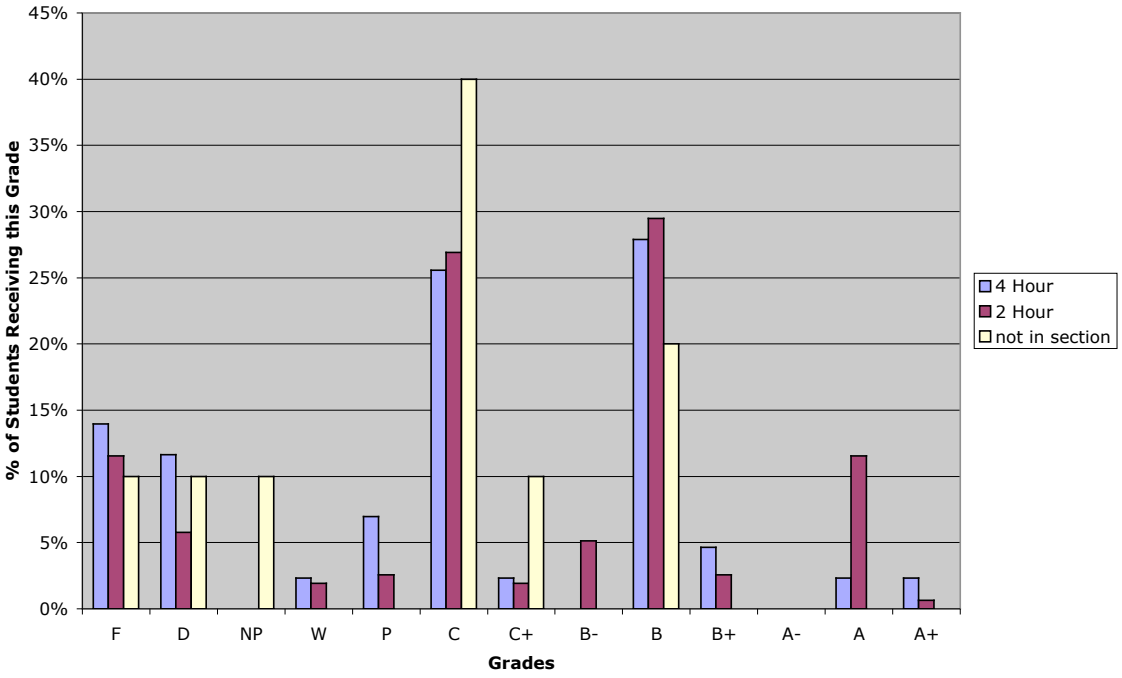
Pre-Test Score	# of Students with this Score	% Students who Passed the Class With this Score
5	2	50% (1)
6	1	100% (1)
9	1	100% (1)
10	1	100% (1)
11	6	67% (4)
12	5	80% (4)
13	6	67% (4)
14	14	71% (10)
15	7	100% (7)
16	8	75% (6)
17	10	70% (7)
18	6	100% (6)
19	10	90% (9)
20	8	63% (5)
21	9	100% (9)
22	3	67% (2)
23	7	57% (4)
24	4	100% (4)
25	6	83% (5)
26	4	75% (3)
27	7	71% (5)
28	2	100% (2)
29	2	100% (2)
30	1	100% (1)
31	1	100% (1)
32	2	50% (1)
33	2	100% (2)
34	3	100% (3)
35	2	100% (2)
36	1	0% (0)
39	1	100% (1)

Appendix 2: Math 2 Grade Distribution by Section

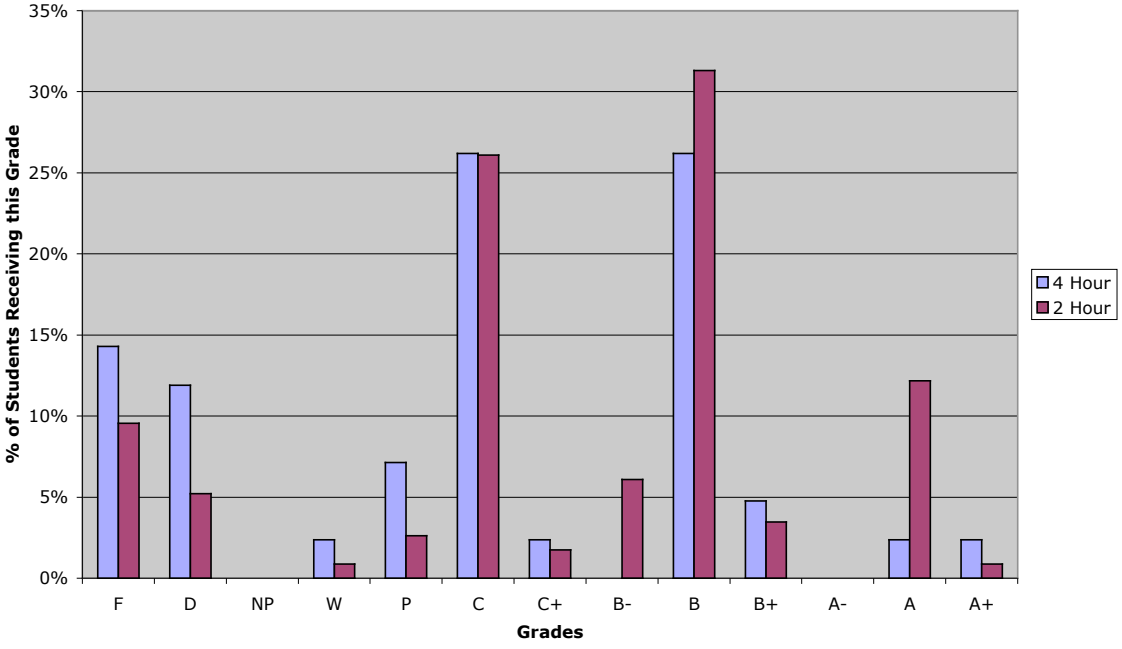




Math 2 Fall 2004 Grade Distribution by Section



Math 2 Fall 2004 Grade Distribution by Section of Students Who Were in the Recommended Section



Appendix 3: Math 3 Pre-Test Scores and Pass Rates

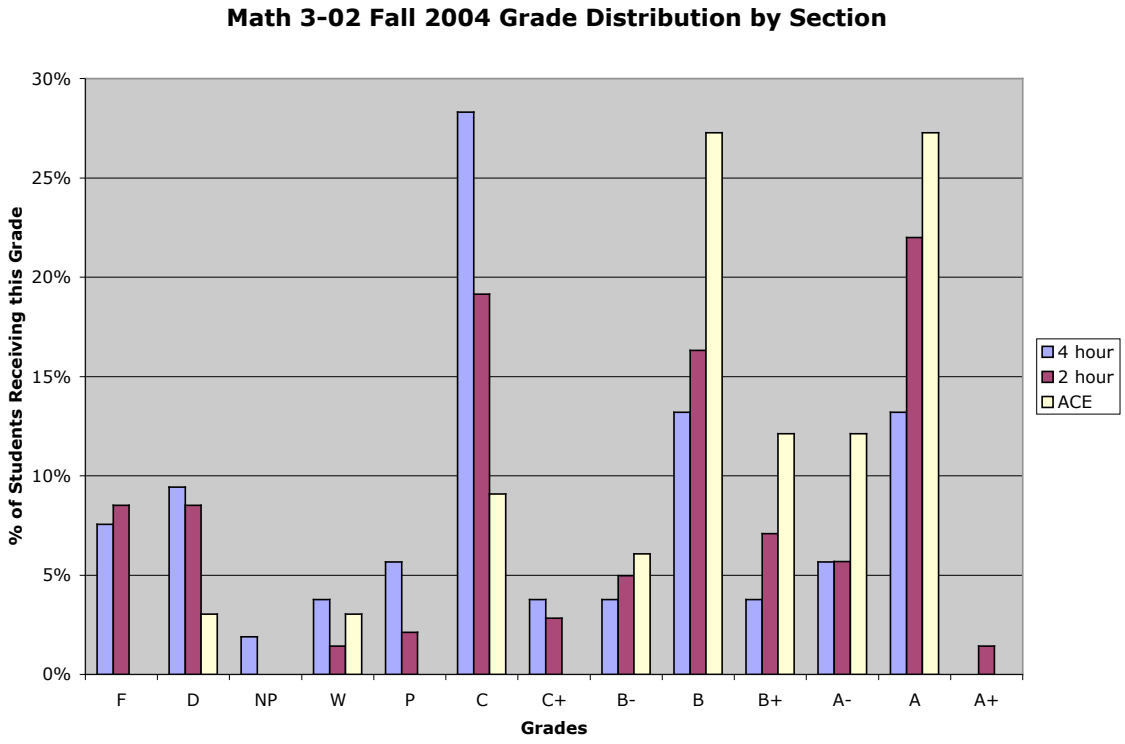
Spring 2004 Math 3
Pre-Test Score and the % of Students who Passes the Class with this Score
Test # MR45A92

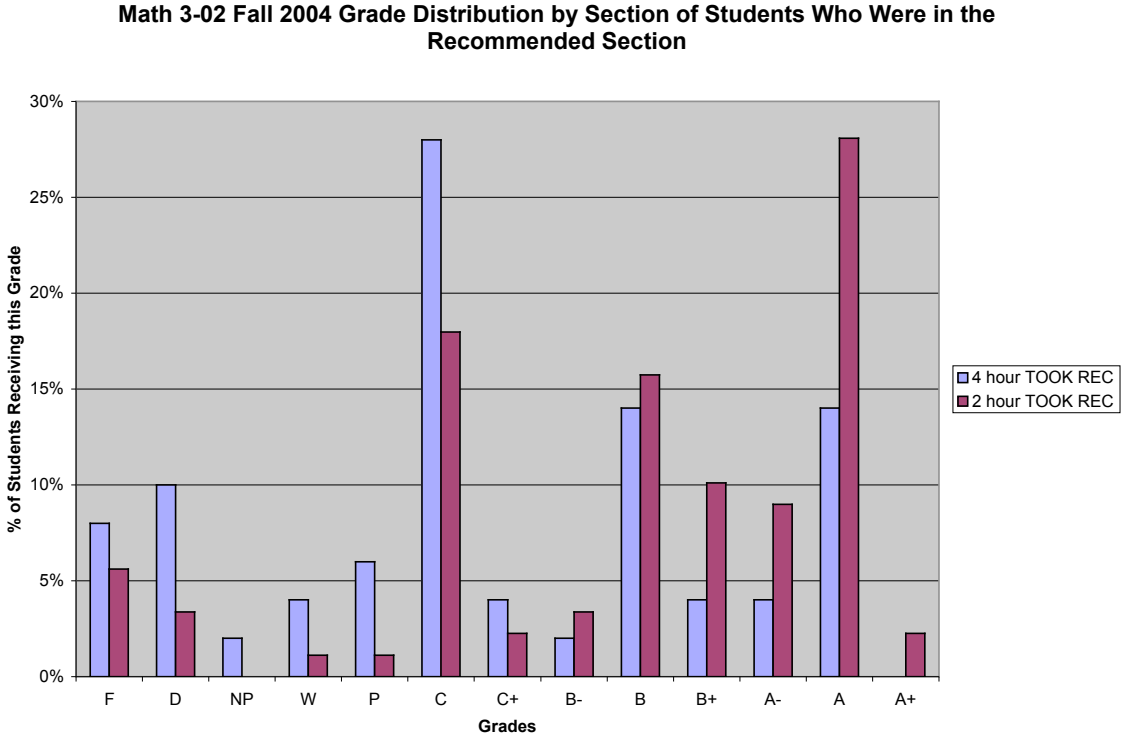
Pre-Test Score	# of Students with this Score	% Students who Passed the Class With this Score
5	2	50% (1)
6	1	0% (0)
7	3	33% (1)
8	3	0% (0)
9	4	25% (1)
10	4	75% (3)
11	7	14% (1)
12	18	28% (5)
13	11	36% (4)
14	21	33% (7)
15	14	50% (7)
16	19	53% (10)
17	22	64% (14)
18	19	53%(10)
19	14	57% (8)
20	11	55% (6)
21	16	56% (9)
22	12	58% (7)
23	12	67% (8)
24	5	80% (4)
25	4	75% (3)
26	5	80% (4)
27	3	67% (2)
28	3	67%2 (2)
29	4	100% (4)
30	3	100% (3)
31	1	100% (1)
32	2	50% (1)

Fall 2004 Math 3-02
Pre-Test Score and the % of Students who Passes the Class with this Score
Test # MR45A92

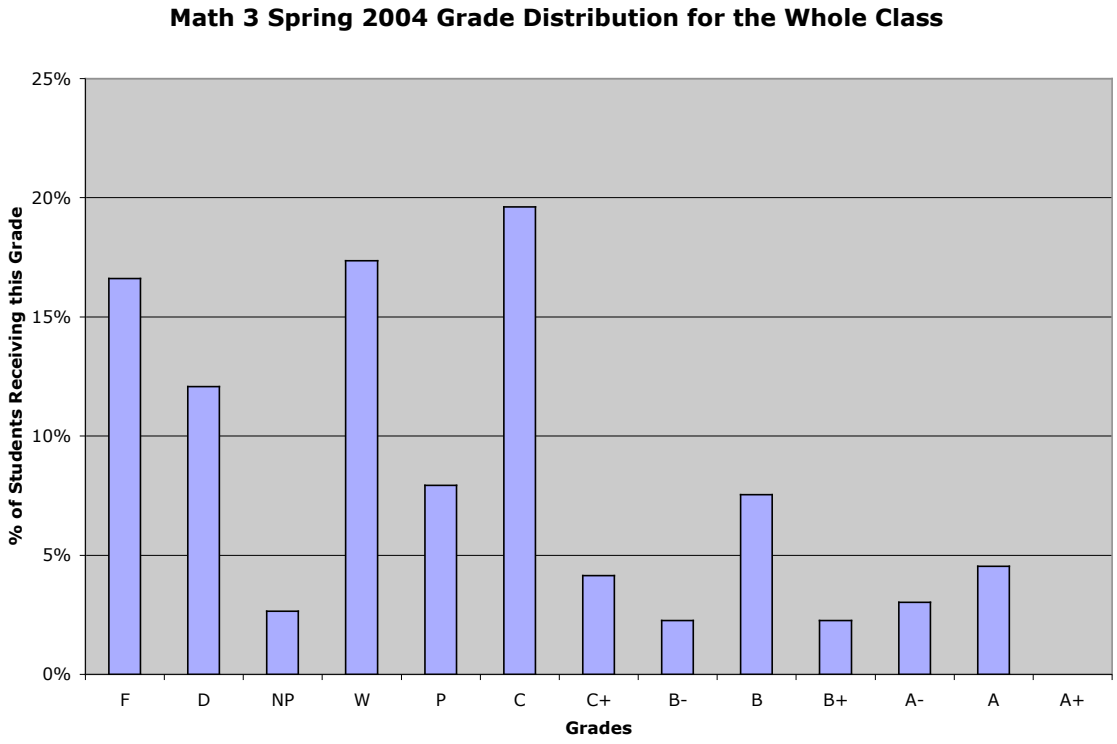
Pre-Test Score	# of Students with this Score	% Students who Passed the Class With this Score
7	1	100% (1)
8	1	0% (0)
9	2	0% (0)
10	1	0% (0)
11	2	100% (2)
12	6	50% (3)
13	5	40% (2)
14	11	82% (9)
15	17	65% (11)
16	11	64% (7)
17	12	100% (12)
18	18	83% (15)
19	10	90% (9)
20	14	79% (11)
21	15	93% (14)
22	14	93% (13)
23	11	91% (10)
24	14	86% (12)
25	8	100% (8)
26	10	80% (8)
27	5	100% (5)
28	8	88% (7)
29	6	100% (6)
30	4	75% (3)
31	3	100% (3)
32	3	100% (3)
33	2	100% (2)
34	1	0% (0)

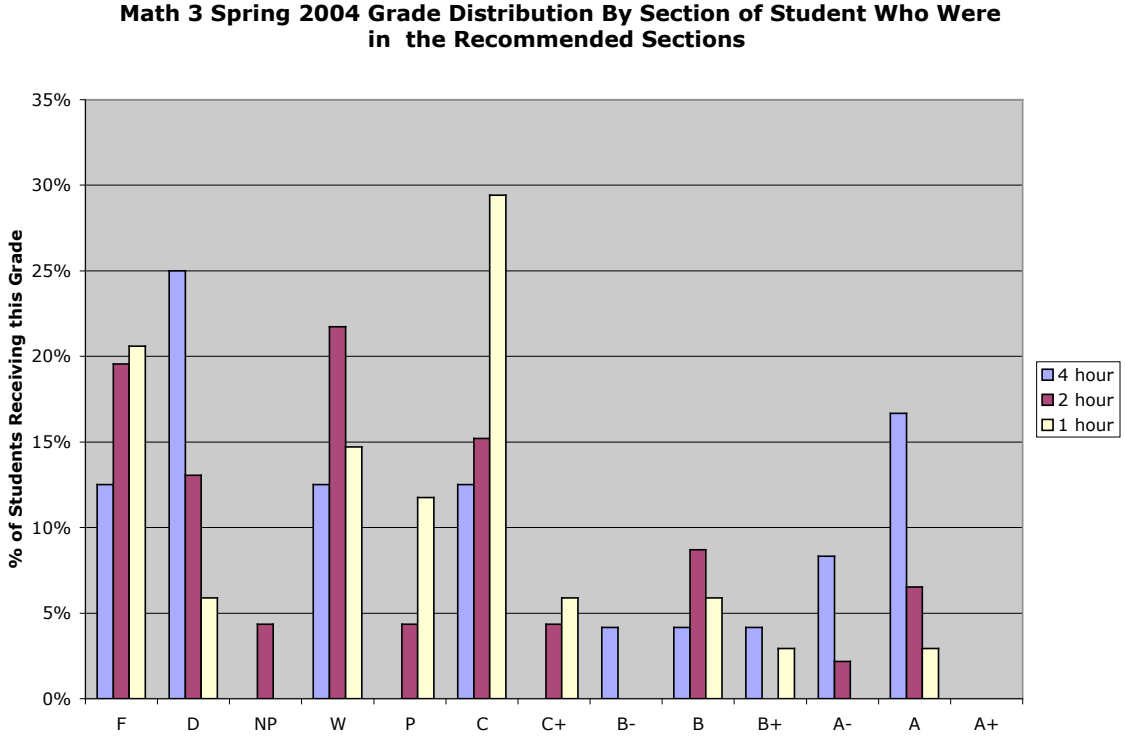
Appendix 4: Math 3-02 Fall 2004 Grade Distribution by Section



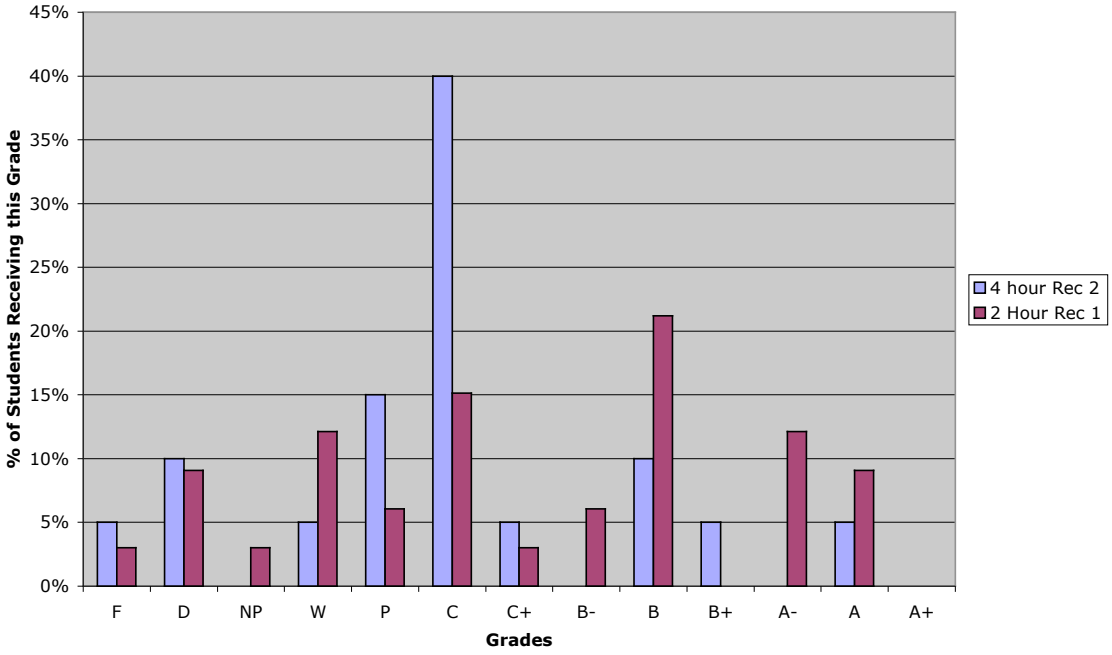


Appendix 5: Math 3 Spring 2004 Grade Distributions

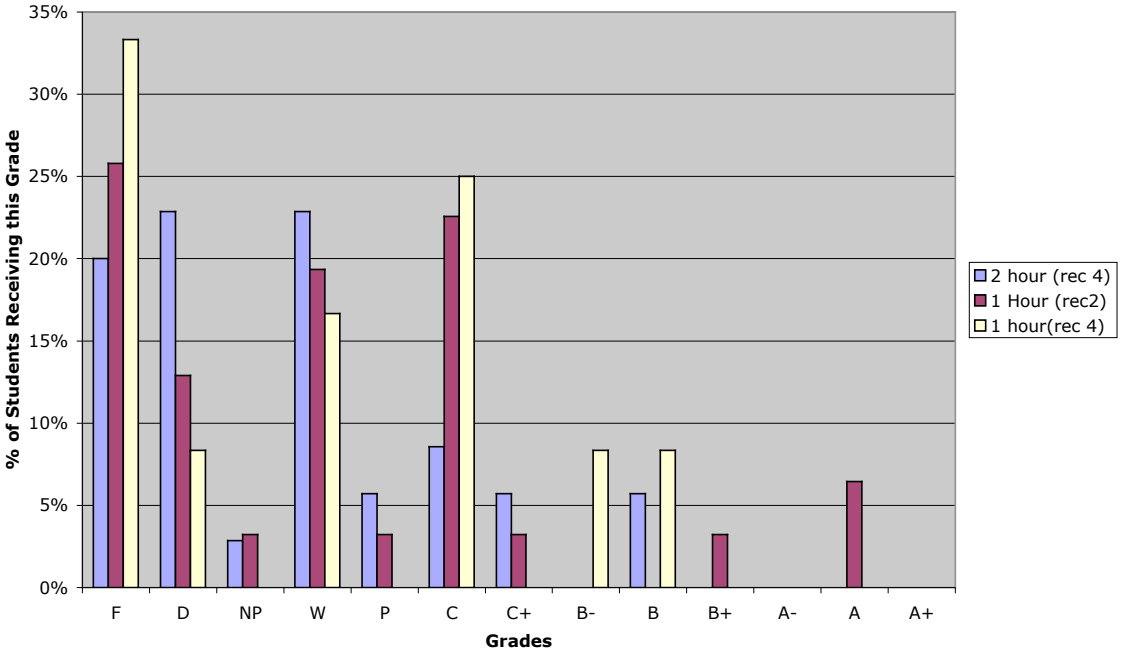




Math 3 Spring 2004 Grade Distribution by Section for Students who went to More Section than Recommended



Math 3 Spring 2004 Grade Distribution By section For Students Who Went to Less hours of Section than Recommended



Appendix 6 – Sample Student Course Records Across Majors

Area of Interest Psychology

Major	Math SAT	MPE	Math 2	Math 3		Select lower div. Course from major		Comments
			Grade	Class/Year	Grade	Class/ year	Grade	
Pre-Psych	460	15	C	Fall '04	F	Psych 1 (W '04)	B-	
Pre-Psych	470	13	C	Spr '04	W	Took lower division courses at Community College		Taking upper division courses getting A's and B's
Proposed Psych	470	13	F			Math 2 (W'05)	B	
Proposed Psych	?	13	C+	Spr '04 F '04	NP C+	Psych 1 (Spr '01) Psych 2 (W '05)	B- B-	

Area of Interest Engineering

Major	Math SAT	MPE	Math 2	Math 3		Select lower div. Course from major		Comments
			Grade	Class/Year	Grade	Class/ year	Grade	
Proposed EE	450	15	C	Spr '04 W '05	F C			Pre-Psych major
Proposed Computer Science	430	19	A-	Spr '05	C	CS 12A (F'05) CS 12A (W'05) CS 12L (F '04) CS 12L (W'05) Math 19A (F '04) Math 19A (W' 05)	D B B- A D F	

Area of Interest Biology

Major	Math SAT	MPE	Math 2	Math 3		Select lower div. Course from major		Comments
			Grade	Class/Year	Grade	Class/ year	Grade	
Proposed Biology	480	19	B	Spr '04	B	Chem 1A (F '03)	W	Not enrolled '04-05
Marine Bio	430	18	B-	Spr '04	C	Chem 1A (F '04) Chem 1B (W '05) Bio 3 (W '05) Math 11A (F'04) Math 11B (W'05)	B B+ B B+ B-	
Proposed Marine Bio	450	17	F			Chem 1A (F'02)	W	Community Studies major (W'05)
Molecular, Cell, and developmental Biology	470	15	B-	Spr '04	C	Bio 20A (Spr '04) Bio 20B (F '04) Bio 20C (W'05) Chem 1A (F '03) Chem 1B (W'04) Chem 1C (Spr '04) Math 11B (F '04) Math 22 (W '05)	C C A- B- B+ C B+ C+	

Area of Interest Economics

Major	Math SAT	MPE	Math 2	Math 3		Select lower div. Course from major		Comments
			Grade	Class/Year	Grade	Class/ year	Grade	
Business Management Economics	500	20	C	Spr '04 F '04	W P	Econ 1 (F '03) Econ2 (W '04) AMS 11A (W '05)	B- C+ F	
Global Economics	530	15	B			Econ 1 (F '02) Econ 2 (W '04)	A B-	American studies Major Educ Minor (W '05)
Business Management Economics	340	12	C+	S '04	C	Econ1 (W '04) Econ 1 (S '04) Econ 11A (Sum '04)	F C A-	

Appendix 7 – Training Course Materials

MATH 188

TRAINING COURSE FOR MSI LEARNING ASSISTANTS
MATH 2 & MATH 3

FALL, 2004

INSTRUCTORS: Frank Bauerle & Gayle Alvarado
Contact Information Frank Bauerle, 271 Kerr Hall
Email, Bauerle@ucsc.edu Phone, 459-2964
Gayle Alvarado, 2nd floor, ARC
Email, galvarad@ucsc.edu Phone, 459-4414

PURPOSE

The purpose of this course is to provide systematic, formal training in instructional strategies and a review of the mathematical concepts covered in Math 2 and Math 3 for the MSI Learning Assistants leading required guided peer learning group style discussion sections. The emphasis will be on equipping these Learning Assistants to plan and implement effective problem-solving experiences concurrent with the week-by-week course lectures.

OBJECTIVES

To review the math concepts covered in Math 2 and Math 3.

To explore, through discussion and practice, effective interactive learning strategies and their application to assisting students to master Math 2 and Math 3 material.

To provide Learning Assistants with effective techniques for creating problem solving exercises, exam review sessions, short quizzes, and blackboard strategies.

To assist Learning Assistants to recognize and assist students suffering from Math anxiety and/or test anxiety.

To teach learning assistants how to read and evaluate students' homework, quizzes, and tests so as to determine what they know and what they still need to learn.

TEXTBOOKS

Course Reader

COURSE REQUIREMENTS

Attend all class sessions.

Complete assigned reading and homework problems prior to class.

Complete all course assignments according to the specified due dates:
- Weekly quiz and practice test design assignment – Due Oct. 11
- Teaching demonstration assignment – Due Nov. 1
- Observation and analysis of a peer-guided learning session assignment – Write-up Due Nov. 8
- Position paper on one aspect of effective Math education – Due Nov. 29

You will receive a detailed handout describing each assignment.

Take the Math 2 or Math 3 Midterm and Final Examination (not for a grade)

COURSE SESSIONS

Attend the required Learning Support Services MSI learning assistant/tutor training on Saturday Oct. 4 from 9:00 to 4:00, Oakes Learning Center

Session 1 – Oct. 2
- Role and Responsibility of a Math 2 or Math 3 MSI Learning Assistant
- Group Management Techniques
- Leading Interactive Group Problem-Solving

Sessions 2 – 9 will be held in the Academic Resources Center, Room 202

Session 2 – Oct. 4
- Effective blackboard strategies
- Teaching students how to use Math textbooks
- Continued practice teaching problem solving strategies

Session 3 – Oct. 11
- Techniques for making quizzes
- Continued discussion of assessing students' learning

Assignment Due – Weekly quiz construction and evaluation (See handout for details)

Session 4 – Oct. 18
- Theory and practice of grading Math exams
- Developing and implementing exam review sessions

Assignment Due – Teaching Demonstrations (See handout for details)

Session 5 – Oct. 25
- Recognizing and assisting students experiencing Math anxiety and/or test anxiety (reading)
- Continued discussion of interactive instructional strategies

Discussion and practice – Asking good questions, Developing listening skills

Session 6 – Nov. 1

Discussion and practice – Asking good questions, Developing listening skills
Assignment Due – Teaching demonstrations (see handout for details)

Session 7 – Nov. 8

Teaching demonstrations
Assignment Due – Teaching Demonstrations
Write-up of a peer observation (See handout for details.)

Session 8 – Nov. 15

Helping students to put it all together – developing and implementing interactive
Final exam review sessions

Session 9 – Nov. 29

Logistics of final exam review sessions, the final exam and grading
Presentations – Positions on math education
Assignment Due – Position paper on Mate education (See handout for details.)

Each course session will involve lecture/discussion and instructional practice using assigned problems from Math 2 and Math 3.

Assignment #1
Weekly Quiz Construction and Evaluation

PURPOSE:
The purpose of this assignment is to give you practice in deciding how to asses students' learning, developing an appropriate instrument, determining how you will evaluate students performance, and evaluating the degree to which the quiz met your expectations.

DIRECTION:
Please think carefully and prepare a written document within which you respond to each of the following steps in this assignment.

Step 1: Identify the most important concepts which you feel students need to learn for a given week. Name these concepts, discuss why you consider them to be most important, and describe the type of problems which students should be able to solve to demonstrate their mastery of the concepts. (This step asks you to explain how and why you will assess student's understanding).

Step 2: Develop a quiz which includes problems which will allow you to determine whether or not students have mastered the concepts which you discussed in step 1. For this step we will like to see your quiz so please include directions as well as the problems.

Step 3: In advance, work through the problems and decide how you will eventually score student's responses. Ask yourself important questions including: how much credit should students receive for each step in the problem solving process, how correct do student's work and answers need to be in order for them to have demonstrated mastery of the material. Explain your scoring decisions in detail.

Step 4: Give the quiz in section.

Step 5: Score the quizzes or guide the students through the quiz scoring process.

Step 6: Collect the quizzes and assess both individual students' performance and the section performance as a whole. Discuss what concepts student's mastered and why and what concepts students are still struggling with and why.

Step 7: Evaluate the effectiveness of your quiz then discuss interactive instructional strategies that you will use to re-teach concepts which the majority of the students did not master and what recommendations you might make to students who did not master the material (such as attending MSI, signing up for tutoring or reviewing the material).

Please submit this assignment double-spaced and typed because we know that many of you will produce outstanding work with your permission we would like to submit your work to the Committee on Teaching and other future math assistants.

Assignment #2
Teaching Demonstration

PURPOSE: The purpose of this assignment is to encourage you to develop a short lesson and practice your pedagogical expertise in a safe and friendly environment where you can receive helpful feedback from your peers. In general, it is important for you to follow the following steps when you teach a lesson: set goals, develop a plan, prepare necessary materials, present the lesson in an interactive context, assess students' learning and evaluate your effectiveness. Please follow the following steps when preparing your teaching demonstration and submit a lesson plan and a self-evaluation.

Step 1: Planning your lesson. For purposes of this assignment please choose only a 15 minute segment of a section in order to practice your teaching strategies. This means that you may have to choose a small part of larger concept. For example, you would not be able to choose the concept of a function but you might be able to choose... Your lesson plan should include your goal, any materials that you will need, a step by step discussion of how you will present the material, including the major points which you will make in the interactive strategies which you will ask students to use, your strategy for assessing students learning (you may not have time to try out your in class or out of class assessment strategies but you should include them in your written plan).

Step 2: Teaching demonstration. Teach your short lesson to your group of peers, you will need to sign up in advance.

Step 3: Ask your peers for feedback.

Step 4: Write a brief self-evaluation discussing the effectiveness of your lesson and indicating any change you might make when you teach this concept in the future.

Please submit this assignment double-spaced and typed because we know that many of you will produce outstanding work with your permission we would like to submit your work to the Committee on Teaching and other future math assistants.

Assignment #3
Peer Observation and Write-Up

PURPOSE:
The purpose of this assignment is to allow you to gain new insight and explore new ways of implementing interactive learning strategies and assist students to become independent learners, while addressing their questions and concerns regarding course content. Watching another educator is an excellent way to learn more about yourself, students, and the teaching-learning dynamic.

SUGGESTED PROCEDURE:

1. Talk with another student in the class or a tutor or MSI learning assistant who has taken the Community Studies MSI/Tutor Training class previously and arrange to observe one of his/her sessions. Please observe a session which is in your area of expertise, the same area for which you are a tutor or an MSI learning assistant.

2. Observe the session and take notes about what you see. Focus on both how the tutor/learning assistant structures the session and the responses of the students.

3. Write a detailed discussion of your observation. Include detailed comments answering each of the following questions:

    a. What seemed to be the tutor/learning assistant's goal for the session?
    b. Recount what went on during the session.
    c. What interactive learning strategies did the tutor/learning assistant use?
    d. What questions did the students ask?
    e. What did the students understand and what seemed to be most difficult for them?
    f. What were the strengths of the session?
    g. What did you learn from watching the session, and how will you use what your learned as you plan and implement your own tutoring/MSI sessions?

4. If you feel comfortable doing so, talk about the session with the tutor/MSI learning assistant whom you observed.

All papers should be typed, double-spaced. Be sure to include your name, the name of the person whom you observed, and the date, time, and location of the session.

Assignment #4
Final Course Paper

PURPOSE:
The purpose of this assignment it to encourage you to analyze your experiences as an MSI Learning Assistant/Teaching Assistant so as to identify a hypothesis regarding an aspect of teaching and learning. You will be writing a position paper within which you will use detailed description and analysis of your MSI experience to support a general observation about teaching and learning which you wish to communicate to Learning Support Services student and professional staff.

PROCESS:

1. Keep session-by-session records in a journal.
2. Think about general ideas about teaching and learning which emerge from your interactions with students and the course content.
3. Develop a hypothesis which you can support with examples from your MSI experience.
4. Write a paper which supports your hypothesis-thesis. You will need to use detailed descriptions of interactions between students and/or between you and students, and your analysis of these interactions to support your thesis. (Please create pseudonyms for the students, rather than using their real names.) You will find samples of this type of a paper in the Community Studies reader on pages 201-219. (See me to borrow a copy of the reader to read the sample paper).
5. Bring a rough draft of your paper to share with peers on November 29.

This paper should be approximately 3 to 5 pages double-spaced. It is to be a formal essay which carefully supports a thesis regarding an aspect of teaching and learning.