Follow-up and Attendance Study
Math 2417 – Calculus I
Fall 2006

In July of 2006 I submitted to the Math Advisory Committee a report on student performance and throughput in several mathematics classes within the undergraduate university. One component of this report analyzed the validity of existing placement benchmarks for allowing entering freshmen to enroll in Math 2417 (Calculus I), the characteristics of students enrolled in the class, and their academic performance. The committee agreed we should replicate these analyses for fall 2006 as consensual validation of the prior findings and add a small empirical study examining the value of having class attendance contribute to students' final grades. This report summarizes these findings. For the sake of presentation, academic grades have been reduced to whole-letter grades.

Grades from fall 2006 provide us a second opportunity to determine the utility of the entry criteria set for admitting first-time freshmen into Calculus 2417. One such criterion was a score of 3 or better on the Advanced Placement Calculus AB or BC test. The expectation (based on historical analysis) was that at least 80% of those graduating seniors with an AP Calculus equal or greater than three would receive a grade of 'C' or better in Calculus 2417. As Table 1 illustrates, in fall 2005 about 85% of the students with a qualifying AP score received a grade of 'C' or better in first-semester calculus. For fall 2006, this rose to 91%. Interestingly, there was a 40% increase in the number of freshmen who completed an AP Calculus Test this year compared to fall 2005. The advanced placement test standard seems to be very useful as a screening measure for calculus readiness. I remain perplexed why 15% of these students were allowed to take 2417 with an AP score less than three and will ask the Director of Undergraduate Advising to research these cases.

Performance on the Scholastic Aptitude Test Mathematics IIC test was also used as a placement criterion with students who scored at or above 630 allowed to enter Calculus I. Using this benchmark, 79% of those qualifying students made a grade of 'C' or better in entering calculus for fall 2005 (See Table 2). For fall 2006, this percentage increased to 89%. As with the AP benchmark, our SAT IIC threshold for entering the calculus sequence seems adequate. We will investigate further the individual students who were placed in this class without meeting the threshold requirement of a score of at least 630.

While not tabled for this report, the SAT IC threshold performance of 630 proved inadequate. This test has been used with students who did not complete a calculus class in high school. For 2005, only 59% of the students at or above that score received a grade of at least 'C' in Calculus 2417. Last fall, that value fell to 58%. The math committee should consider carefully whether this test could be a useful predictor at any threshold. It might be better to simply require any student who has not completed a high school calculus class to complete a pre-calculus course prior to 2417.

Table 3 reviews the academic grade distribution for Calculus 2417 for fall 2005 and fall 2006. A primary finding of the previous report was the high (40.66%) 'DFW' rate of students in the fall 2005 semester. Further analysis illustrated that the rate was a composite aggregated from subgroups with very different success rates in the class. First-time freshmen had the lowest 'DFW' rate (28.08%), while third-semester freshmen, many who had attempted the course previously, had the highest rate (71.43%). The composite rate for non-freshmen was 57%. The overall 'DFW' rate dropped by three percent for fall 2006. Most of the change resulted from of an almost eight percent drop for first-time freshmen. For continuing freshmen, the 'DFW' rate dropped eight percent while the composite rate for non-freshmen rose to 62%. It remains clear that continuing students have the most difficulty with Calculus 2417.

The grade distributions for Math 2417 for the last two fall semesters make clear a distinction that we must appreciate. Calculus I is a so-called gateway class, meaning it stands as the portal to a series of courses in mathematics critical to the degree requirements in a number of academic disciplines. It is also a class most often taken by first-semester freshmen. However, the concept of a gateway class and a freshman class must not be confused. As these data illustrate, Math 2417 is not necessarily a large obstacle for entering freshmen. However, it is a major roadblock to the academic plans to many other students.

This can be further illustrated by looking at the Math 2417 'DFW' rate for undergraduate students by classification for the fall 2006 semester in comparison to the undergraduate average 'DFW' rate for all classes that semester. For our purposes, I have distinguished first-semester from continuing freshmen. While the 'DFW' rate in Calculus 2417 for fall 2006 was 37.16%, (See Table 3) the overall 'DFW' rate for the undergraduate university for that semester was 14.63% including this calculus class. Put another way, the 'DFW' rate for this calculus class was 2.5 times greater than for the average university class. This dropped to only 1.4 times greater for incoming freshmen but 4.29 times greater for continuing freshmen, 4.16 times greater for sophomores, 4.83 times greater for juniors, and 3.50 times greater for seniors (See Figure 1). In fact, if you are not a first-time freshman, you are over four times more likely to be in the 'DFW' category for Calculus 2417 than for your other undergraduate classes as a whole.

Another perspective on this issue can be gained from the analysis of a small study conducted in Math 2417 during fall 2006. The study addressed the question of whether counting attendance as a part of a student's calculus grade would influence the average GPA in classes where this condition was imposed. For purposes of the experiment, three of the six calculus sections were chosen to be in the attendance condition while three were used as controls. As an extra level of control, two instructors were asked to teach classes in each of the two conditions while a third faculty member taught only in the control condition. In the attendance condition, role was taken at each class meeting by an independent observer and returned to faculty on a weekly basis. Attendance data were used to award points counting as one of 10 quizzes which represented 30% of the semester grade. Adequate attendance (no more than three absences) represented 3% of the total points available in the class. Attendance was not taken nor did it count toward the semester grade in the control condition.

The results of this study were analyzed using a three-factor analysis of variance with attendance, instructor, and student classification (status) serving as independent variables and semester grade used as the dependent variable. Adding instructor as a condition allowed for some control over the issue of differential grading across instructors while student classification was important since previous analyses demonstrated that students at different levels received different grades. For the purposes of this analysis, students' status was considered either as first-semester freshmen or as a continuing student. There were 463 students who received grades in Math 2417 for fall 2006. The 'Attendance' condition included

268 students while there were 195 ‘Control’ condition students. First-time freshmen numbered 296 while there were 167 continuing students. Type III sums of squares were employed in the analysis due to the unbalanced nature of the design.

Table 4 presents an overview of the general linear model analysis. There was an overall effect for the model ($F (6.456) = 176.73$, $p < .001$) with the independent variables and their interactions explaining about 20% of the variance in calculus grades. Grades did not vary as a function of the instructor or the interaction between instructor and attendance. However, there was a significant effect for attendance ($F (1,457) = 9.31$, $p = .013$) and the interaction between attendance and status yielded significant results ($F (1,456) = 6, 21$, $p = .01$). The three-way interaction was not significant and is not included in that there were no hypotheses related to that effect.

Table 5 contains the descriptive statistics for each group which gave rise to the various statistical effects. The main effect for attendance results from the higher average calculus grades for students in the attendance condition (2.28) versus the control condition (1.85). It appears that having attendance contribute a small amount to students’ semester grades may improve their performance, presumably by making them more likely to attend class. However, this outcome varies greatly as a function of student status. Within the first-time freshman group, the mean semester grade difference between those in the ‘attendance’ condition (2.56) and the ‘control’ condition (2.49) was slight. For continuing students, those in the ‘attendance’ condition (1.67) averaged much higher grades than those in the ‘control’ condition (1.00). The differential influence of the attendance treatment by level of status is the basis for the significant interaction. Independent of condition, the average semester grade of continuing students (1.34) was much lower than for first-time freshmen (2.56). The simplest interpretation is that coming to class is of some benefit and that benefit increases as your performance in class decreases.

The ‘DFW’ rate for Math 2417 is far higher than for most classes in the undergraduate university. However, the increased difficulty level is not uniform for all students. First-semester freshmen perform much better in this class than any other group. This is hardly surprising in that these students, for the most part, have recently completed a class in calculus in high school and demonstrated their proficiency on a standardized test of calculus knowledge. However, they represent only 60% of the students enrolled in the class. The remaining students qualify for admission to the class as a function of completing a pre-calculus class or having previously failed Math 2417. It seems clear that neither of these experiences are adequate preparation for this class.

One suggestion is to reconsider our first-year calculus sequence. Some years ago we made the decision to compress our traditional three-semester introductory calculus sequence down to two semesters. Many universities continue to use the three-semester strategy. Listed below are the introductory calculus courses offered by Rice University (See Table 6 for complete course descriptions).

- Math 101 – Single Variable Calculus I (3 hours)
- Math 102 – Single Variable Calculus II (3 hours)
- Math 211 – ODE’s and Linear Algebra (3 hours)
- Math 212 – Vector Calculus (3 hours)

These four courses are normally taken in sequence although 211 and 212 are considered relatively changeable. Most engineering students take Math 101 and 102 followed by Math 212. On the other hand, most students in the biological sciences take 101 and 102 followed by 211. Those in the physical sciences take both 211 and 212. Rice also offers two additional introductory courses.

- Math 111 – Fund. Theorem of Calculus (3 hours)
- Math 112 – Calculus Applications (3 hours)

These two classes form a slower paced version of Math 101/102 and teach a reduced palette of functions. Students can take Math 111 followed by Math 101/102 or Math 111/112 followed by Math 102 to complete their basic univariate calculus requirements before moving on to differential equations and multivariate calculus. Rice faculty encourage students to take the most advanced calculus class they can master. If a student has no previous calculus experience they are advised to enroll in Math 101 or Math 111. If Math 101 proves too difficult the student can drop back to Math 111 without penalty. A similar strategy is used by both Stanford and Harvard for their introductory calculus sequences. Rice does not offer classes in precalculus but rather uses the Math 111-112 sequence as a substitute. I recommend we consider such a tactic at UT Dallas. It might even be possible to rethink the applied calculus sequence Math 1325-1326 to serve this purpose. The major drawback is that the applied calculus courses focus primarily on business applications.

I would also suggest that the faculty in mathematics meet again with its major consumer groups (engineering, computer science, life sciences) to reaffirm the content of the calculus sequence (Math 2417 – Math 2419) as it relates to the needs of their students. This discussion should include the School of Management for Math 1325-136.

A third and more immediate recommendation is another small experiment. With the committee's blessing, I would like to offer supplemental instruction in two sections of Math 2417 for fall 2007 that would be taught by upper-division math majors and limited to continuing students. First-semester freshmen could use the Math Lab in the Learning Resource Center for additional support. The supplemental instruction leaders would meet weekly with those interested to further review the information and assignments for that week. Our history with supplemental instruction suggests that participating students make better grades and are less likely to withdraw from classes than their peers who do not take advantage of the service.

Table 1

Grade Distribution by AP Calculus Score for Math 2417 Fall 2005 and Fall 2006

AP SCORE		LETTER GRADE FALL 2005 A	B	C	D	F	W	TOTAL
5	NUMBER	12	11	7		1	1	32
	PERCENT	37.50%	34.38%	21.88%	0.00%	3.13%	3.13%	100.00%
4	NUMBER	4	11	5	1	4		25
	PERCENT	16.00%	44.00%	20.00%	4.00%	16.00%	0.00%	100.00%
3	NUMBER		7	9	1	4		21
	PERCENT	0.00%	33.33%	42.86%	4.76%	19.05%	0.00%	100.00%
2	NUMBER		2	2	2	4		10
	PERCENT	0.00%	20.00%	20.00%	20.00%	40.00%	0.00%	100.00%
1	NUMBER			2	2			4
	PERCENT	0.00%	0.00%	50.00%	50.00%	0.00%	0.00%	100.00%
TOTAL NUMBER		16	31	25	6	13	1	92
TOTAL PERCENT		17.39%	33.70%	27.17%	6.52%	14.13%	1.09%	100.00%

Accurate Placement Rate = 66/78 = 85%

AP SCORE		LETTER GRADE FALL 2006 A	B	C	D	F	W	TOTAL
5	NUMBER	20	9	4				33
	PERCENT	60.61%	27.27%	12.12%	0.00%	0.00%	0.00%	100.00%
4	NUMBER	15	21	16	1	2	1	56
	PERCENT	26.79%	37.50%	28.57%	1.79%	3.57%	1.79%	100.00%
3	NUMBER	7	14	12	1	5	2	41
	PERCENT	17.07%	34.15%	29.27%	2.44%	12.20%	4.88%	100.00%
2	NUMBER	1	7	4	2	1	1	16
	PERCENT	6.25%	43.75%	25.00%	12.50%	6.25%	6.25%	100.00%
1	NUMBER		3	1	1	2		7
	PERCENT	0.00%	42.86%	14.29%	14.29%	28.57%	0.00%	100.00%
TOTAL NUMBER		43	54	37	5	10	4	153
TOTAL PERCENT		28.10%	35.29%	24.18%	3.27%	6.54%	2.61%	100.00%

Accurate Placement Rate = 118/130 = 91%

Table 2

Grade Distribution by SAT IIC Score Range for Math 2417 Fall 2005 and Fall 2006

			LETTER GRADE FALL 2005						
TEST	SAT II RANGE	Data	A	B	C	D	F	W	TOTAL
SAT IIC	760-800	NUMBER	6	5	2		1		14
		PERCENT	42.86%	35.71%	14.29%	0.00%	7.14%	0.00%	100.00%
	710-750	NUMBER	6	3	2	2			13
		PERCENT	46.15%	23.08%	15.38%	15.38%	0.00%	0.00%	100.00%
	690-700	NUMBER	1	7		1	1	1	11
		PERCENT	9.09%	63.64%	0.00%	9.09%	9.09%	9.09%	100.00%
	670-680	NUMBER		2	2			1	5
		PERCENT	0.00%	40.00%	40.00%	0.00%	0.00%	20.00%	100.00%
	660-650	NUMBER	1	6	6		2		15
		PERCENT	6.67%	40.00%	40.00%	0.00%	13.33%	0.00%	100.00%
	640-640	NUMBER		3		1	2		6
		PERCENT	0.00%	50.00%	0.00%	16.67%	33.33%	0.00%	100.00%
	630-630	NUMBER		1	4	2	1		8
		PERCENT	0.00%	12.50%	50.00%	25.00%	12.50%	0.00%	100.00%
	530-620	NUMBER		2	1	5	1		9
		PERCENT	0.00%	22.22%	11.11%	55.56%	11.11%	0.00%	100.00%
	TOTAL	NUMBER	14	29	17	11	8	2	81
	TOTAL	PERCENT	17.28%	35.80%	20.99%	13.58%	9.88%	2.47%	100.00%

Accurate Placement Rate = 59/72 = 79%

			LETTER GRADE FALL 2006						
TEST	SAT II RANGE	Data	A	B	C	D	F	W	TOTAL
SAT IIC	760-800	NUMBER	2	1	1		1		5
		PERCENT	40.00%	20.00%	20.00%	0.00%	20.00%	0.00%	100.00%
	710-750	NUMBER	8	7	1	1	1		18
		PERCENT	44.44%	38.89%	5.56%	5.56%	5.56%	0.00%	100.00%
	690-700	NUMBER	3	1	3				7
		PERCENT	42.86%	14.29%	42.86%	0.00%	0.00%	0.00%	100.00%
	670-680	NUMBER	4	5	4	1	2		16
		PERCENT	25.00%	31.25%	25.00%	6.25%	12.50%	0.00%	100.00%
	660-650	NUMBER	5	7	2	1	1		16
		PERCENT	31.25%	43.75%	12.50%	6.25%	6.25%	0.00%	100.00%
	640-640	NUMBER	4	2	5				11
		PERCENT	36.36%	18.18%	45.45%	0.00%	0.00%	0.00%	100.00%
	630-630	NUMBER		2	1			1	4
		PERCENT	0.00%	50.00%	25.00%	0.00%	0.00%	25.00%	100.00%
	530-620	NUMBER	4	5	7	1	2	1	20
		PERCENT	20.00%	25.00%	35.00%	5.00%	10.00%	5.00%	100.00%
	TOTAL	NUMBER	30	30	24	4	7	2	97
	TOTAL	PERCENT	30.93%	30.93%	24.74%	4.12%	7.22%	2.06%	100.00%

Accurate Placement Rate = 68/76 = 89%

Table 3
Grade Distribution by Class Status for Math 2417 Fall 2005 and Fall 2006

CLASS		LETTER GRADE - FALL 2005									
		A	B	C	D	F	W	WF	WP	TOTAL	DFW
ENTERING FRESHMEN	NUMBER	54	89	67	27	41	4	6	4	292	
	PERCENT	18.49%	30.48%	22.95%	9.25%	14.04%	1.37%	2.05%	1.37%	100.00%	28.08%
CONTINUING FRESHMEN	NUMBER		1	11		27	1	2		42	
	PERCENT		2.38%	26.19%		64.29%	2.38%	4.76%		100.00%	71.43%
SOPHOMORE	NUMBER	6	5	14	11	19	5	5	2	67	
	PERCENT	8.96%	7.46%	20.90%	16.42%	28.36%	7.46%	7.46%	2.99%	100.00%	62.69%
JUNIOR	NUMBER	2	6	15	4	17	7	7		58	
	PERCENT	3.45%	10.34%	25.86%	6.90%	29.31%	12.07%	12.07%	0.00%	100.00%	60.34%
SENIOR	NUMBER		8	8	1	5		1		23	
	PERCENT	0.00%	34.78%	34.78%	4.35%	21.74%	0.00%	4.35%	0.00%	100.00%	30.43%
TOTAL NUMBER		62	109	115	43	109	17	21	6	482	
TOTAL PERCENT		12.86%	22.61%	23.86%	8.92%	22.61%	3.53%	4.36%	1.24%	100.00%	40.66%

CLASS		LETTER GRADE - FALL 2006									
		A	B	C	D	F	W	WF	WP	TOTAL	DFW
ENTERING FRESHMEN	NUMBER	84	91	69	18	33		9	4	308	
	PERCENT	27.10%	29.35%	22.26%	5.81%	10.65%	0.00%	2.90%	1.29%	100.00%	20.65%
CONTINUING FRESHMEN	NUMBER	3	3	10	8	13	1	4	1	43	
	PERCENT	6.98%	6.98%	23.26%	18.60%	30.23%	2.33%	9.30%	2.33%	100.00%	62.79%
SOPHOMORE	NUMBER	3	9	13	8	27		3	1	64	
	PERCENT	4.69%	14.06%	20.31%	12.50%	42.19%	0.00%	4.69%	1.56%	100.00%	60.94%
JUNIOR	NUMBER		8	9	11	16	3	10	1	58	
	PERCENT	0.00%	13.79%	15.52%	18.97%	27.59%	5.17%	17.24%	1.72%	100.00%	70.69%
SENIOR	NUMBER	3	9	7	2	6	4	3	5	39	
	PERCENT	7.69%	23.08%	17.95%	5.13%	15.38%	10.26%	7.69%	12.82%	100.00%	51.28%
TOTAL NUMBER		93	120	108	47	95	8	29	12	512	
TOTAL PERCENT		18.09%	23.35%	21.01%	9.14%	18.48%	1.56%	5.64%	2.33%	100.00%	37.16%

Figure 1
Increase in Likelihood of Receiving 'DFW' in Math 2417 Compared to Base Rate for Undergraduate Univeristy

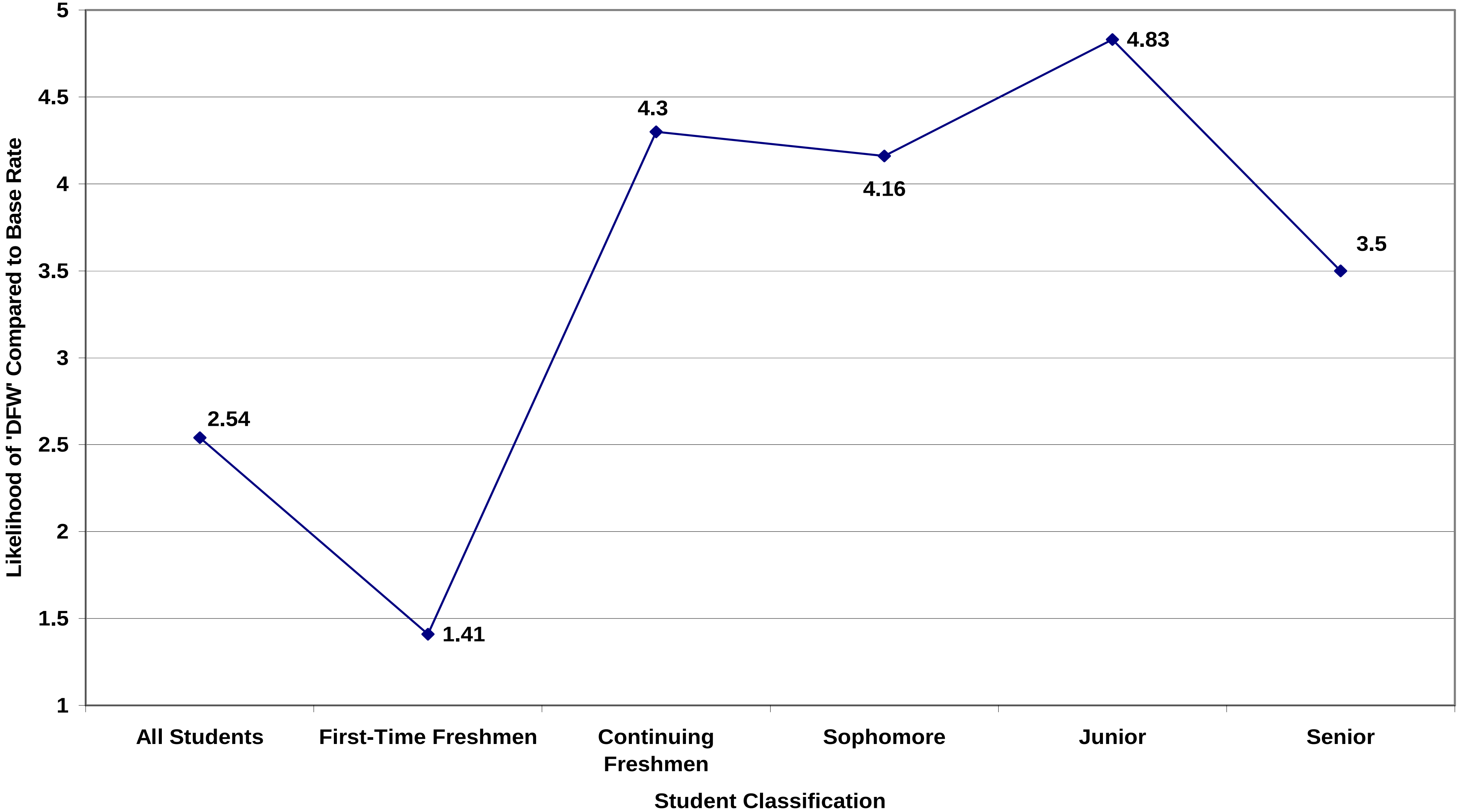

Table 4

The GLM Procedure

Class Level Information

Class	Levels	Values
Condition	2	Attendance Control
Instructor	3	One Two Three
Status	2	First- Semester Freshman Continuing Student

Number of Observations Read	463
Number of Observations Used	463

Dependent Variable: Semester Grade

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	176.7352259	29.4558710	19.42	<.0001
Error	456	691.5695948	1.5166000		
Total	462	868.3048207			

R-Square	Coeff Var	Root MSE	Grade Mean
0.203541	58.52803	1.231503	2.104125

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Condition	1	14.1178549	14.1178549	9.31	0.0024
Instructor	2	3.3957356	1.6978678	1.12	0.3273
Status	1	147.8321095	147.8321095	97.48	<.0001
Cond*Status	1	9.4164512	9.4164512	6.21	0.0131
Cond*Instruct	1	0.4104188	0.4104188	0.27	0.6032

Table 5

Table of Means

Level of Condition	N	Grade Mean	Grade Std Dev
Attend	195	1.85692308	1.42922399
Control	268	2.28399254	1.30029963

Level of Instructor	N	Grade Mean	Grade Std Dev
One	152	2.18710526	1.40694052
Two	241	2.11925311	1.30059933
Three	70	1.87185714	1.51586231

Level of Status	N	Grade Mean	Grade Std Dev
Fresh	296	2.53543919	1.24015656
Continue	167	1.33964072	1.25614628

Level of Condition	Level of Status	N	Grade Mean	Grade Std Dev
Control	Fresh	112	2.48857143	1.30911693
Control	Continue	83	1.00457831	1.11018159
Attend	Fresh	184	2.56396739	1.19899868
Attend	Continue	84	1.67071429	1.30956333

Level of Condition	Level of Instructor	N	Grade Mean	Grade Std Dev
Control	One	56	1.73875000	1.47144093
Control	Two	69	1.93768116	1.31394684
Control	Three	70	1.87185714	1.51586231
Attend	One	96	2.44864583	1.30583760
Attend	Two	172	2.19209302	1.29187213

Table 6

Description of Entering Calculus Courses at Rice University

MATH 101 - SINGLE VARIABLE CALCULUS I Credits: 3 Differentiation, extrema, Newton's method, integration, fundamental theorem of calculus, area, volume, natural logarithm, exponential, arc length, surface area, Simpson's rule, L'Hopital's rule. May substitute MATH 111-112 or take MATH 101 after completing MATH 111. **College:** School of Natural Sciences **Department:** Mathematics

MATH 102 - SINGLE VARIABLE CALCULUS II Credits: 3 Continuation of MATH 101. Includes further techniques of integration, as well as infinite sequences and series, tests for convergence, power series, radius of convergence, polar coordinates, parametric equations, and arc length. **College:** School of Natural Sciences **Department:** Mathematics

MATH 111 - FUNDAMENTAL THEOREM OF CALCULUS Credits: 3 Study of calculus, forming with MATH 112 a slower-paced version of MATH 101/102. Contains less detail in the coverage of infinite series. Students may take MATH 111/112 followed by MATH 102, or MATH 111 followed by MATH 101/102. **College:** School of Natural Sciences **Department:** Mathematics

MATH 112 - CACULUS AND ITS APPLICATIONS Credits: 3 Continuation of the study of calculus from MATH 111. **College:** School of Natural Sciences **Department:** Mathematics

MATH 211 - ORDINARY DIFFERENTIAL EQUATIONS AND LINEAR ALGEBRA Credits: 3 Study of ordinary differential equations (e.g., solutions to separable and linear first-order equations and to higher-order linear equations with constant coefficients, the properties of solutions to differential equations, and numerical solution methods) and linear algebra (e.g., vector spaces and solutions to algebraic linear equations, dimension, eigenvalues, and eigenvectors of a matrix), as well as the application of linear algebra to first-order systems of differential equations and the qualitative theory of nonlinear systems and phase portraits. Use of the computers in Owlnet as part of each homework assignment required. Equivalency: MATH 213. **College:** School of Natural Sciences **Department:** Mathematics

MATH 212 - MULTIVARIABLE CALCULUS Credits: 3 Study of gradient, divergence, and curl, Lagrange multipliers, multiple integrals, as well as line integrals, conservative vector fields, Green's theorem, Stokes's theorem, and Gauss's theorem. May substitute Math 221 and 222. Equivalency: MATH 222. **College:** School of Natural Sciences **Department:**