What Factors in Predict AP Calculus Students' Grades on the National AP Calculus Exam and How Well Do They Predict?

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Abstract

Fueled by their college counselors, a common belief among high school juniors and seniors is that a résumé replete with AP courses is a “must have” for admission not only to the university of their choice, but to any respectable university. SAT scores, grades in previous mathematics classes, and placement tests are used to determine which students can handle the rigor of an AP Calculus class. Invariably, there are a few students who do poorly on the placement test but who still wish to enroll in AP Calculus. Some do well; some do not. On the other hand, students who score well on the placement test do not necessarily do well either in the course or on the national exam. Other mitigating factors, such as participation in athletics or the arts, may affect students’ performance in an AP Calculus class.

There are students who excel at math The goal of this study is to investigate possible predictors for the AP Exam grade and any relationships among several categorical variables, including gender, ethnic minority status, and grade level. Data from one teacher, the author, over a period of several years has been collected and analyzed. Because this data is from only one school and only one teacher, no generalizations to the population of AP Calculus teachers or AP Calculus students is intended. However, larger studies could provide information which could be inferential in nature.

Introduction

Teachers, parents, schools and communities are all interested in offering thorough, appropriate, and rigorous curricular choices for students. The students themselves want a variety of choices to match their interests, goals and abilities. Certainly, no one wants to burden a child with courses which are beyond their ability. Doing so only ends in frustration and disappointment. However, some students, and frequently their parents, overestimate the student's ability to handle a challenging course, especially when the student believes that he needs the course to gain admission to the college of his choice. This is becoming ever more prevalent with the wide availability of advanced placement (AP) courses. Students are convinced that their transcripts must be a laundry list of AP courses, that they must have extracurricular activities in sports and/or the arts, and they must have a record of community service. This results in some students being placed in AP classes for which they are ill-prepared. The prospect of success is questionable. In order to ensure that students are permitted to register only for AP courses in which they have a reasonable expectation of success, many schools require prospective students to pass a placement test.

The school where the study of this report took place requires a placement test for AP Calculus, regardless of previous mathematics classes. The placement test, SAT scores, GPA, grade in other mathematics classes and teacher recommendations are all considered when placement is decided. The placement test, the empirical indicator of how much pre-Calculus the student knows, is arguably the weightiest of these factors. But how well does the placement test predict the student's ultimate success in the course as measured by the grade earned on the AP Calculus national exam? There

are cases of students who performed poorly on the placement test but insisted they would work hard if admitted to the AP Calculus class. Some succeeded; some eventually dropped the course with a failing grade. Some could balance the challenges of the course while still being active in extracurricular activities. Others had more difficulty with the balancing act. On the other hand, students who do well on the placement test are not guaranteed a one-way ticket to success on the national exam. They, too, must balance a busy life with rigorous academics. Some succeed and some do not.

While the grade on the placement test measures pre-Calculus knowledge and skill, the grade which is earned in the AP Calculus course itself is a measure of how well the student actually knows introductory differential and integral calculus. This is the material which is covered in the national exam. How well does performance in the AP Calculus course itself grade predict the grade on the national exam?

Literature Review

According to the College Board (2011), success in AP Calculus is closely tied to the preparation students have had in their earlier mathematics courses; that is, students should have mastery of algebra, geometry, coordinate geometry, trigonometry and extensive knowledge of advanced algebra topics, analytic geometry and elementary functions. Challenging them in middle school with calculus-connected topics such as the path of a thrown ball was suggested by Barger & McCoy (2010), who hypothesize that motivating these students now will result in their undertaking increasingly advanced high school and college math.

Given the rigor of an AP Calculus course, students need to be well prepared for the challenge. Some schools require a certain level of achievement in prior mathematics courses. For example, Gettysburg Area High School (2011) states "school states "you must have done well so far in your math and science courses to choose to take AP Calculus." Logan High School (2011) requires a grade of B or higher in Pre-Calculus. St. Francis High School (2011) requires a grade of either A or B in the preparatory course.

Some schools choose to administer placement tests, from which the students' knowledge of PreCalculus topics can be assessed. These are especially helpful in determining placement for students who are transferring from other school systems and for foreign exchange students, for whom course titles may be nebulous. The intent is to ensure only students who are sufficiently knowledgeable to begin AP Calculus are permitted to enroll.

Skipping some preparatory course work in order to enroll in an AP Calculus course is not only unwise, it is not permitted. The College Board (2011) specifically states, "it should be emphasized that eliminating preparatory course work in order to take an AP course is not appropriate."

Those students who enroll in AP Calculus need to be cognizant of the challenge which they face. Expectations of the College Board (2011) are that "students who take an AP course in Calculus will seek college credit, college placement or both."

This study examines the predictive value of the placement test and major course grades both individually and collectively for the national exam grade. Analyses of the

possible roles of gender, ethnic minority status, grade level, and participation in sports and the arts are also included.

Specifically, the following three questions will be analyzed:

(1) Can the score on the national AP Calculus exam be predicted by the placement test score, midterm exam grade, and final course grade, or by some combination of these three factors? If so, what is the unique contribution of each of these factors in the prediction?

(2) Is there an association between achievement on the national AP Calculus per gender, ethnic minority status and grade level?

(3) Does achievement on the national AP Calculus vary according to participation in the arts and participation in sports?

Methods

Sample

The sample consists of one hundred forty four students who were taught AP Calculus by one teacher. Data have been collected over period of several years.

Data and Data Collection

Data consists of gender (male or female), grade level (sophomore, junior or senior); ethnic minority status (yes or no); placement test score (whole numbers between 15 and 30 inclusive); midterm grade in the AP Calculus course (whole number between 70 and 98, inclusive); final grade in the AP Calculus course (whole numbers between 71 and 97, inclusive); participation in the Arts (yes or no); and, number of sports (0, 1 or 2). Course grades, placement test grades and AP exam grades were

collected from the teacher's records. Data on student gender, ethnic minority status and grade level, participation in the Arts and participation in sports were extracted from school archives. The distribution of students in each grade level by gender is shown in Table 1. The distribution of students by ethnic minority status and gender is shown in Table 2. And, the distribution of students by ethnic minority status by grade level is by gender is shown in Table 3.

Design of the Study

SPSS software was utilized in answering the three research questions.

The first question involves the prediction of a dependent variable, AP Exam score, from three other, presumably, independent variables. Multiple regression is used to determine the percentage of variation in the dependent variable which is explained by the least squares model. Further, the model will also indicate how each of these three potential predictors individually contributes to the prediction of the dependent variable.

The second question addresses any association between gender, ethnic minority status and grade level and the level of achievement on the national AP Calculus exam. Therefore, chi-square tests for association were used.

The third question employs an ANOVA for two factors to address any association between two categorical variables. The two levels for factor 1, participation in the arts, are "0" for no participation and "1" for participation. Participation in the Arts indicates that the student participated in an extra-curricular artistic activity such as school play, the school chorus, the after-hours coffee shop, etc. It does not indicate that the student merely was enrolled in an arts class, such as photography or ceramics. The three levels for factor 2, participation in sports, "0" for no participation, "1" for participation in

either a fall or spring sport, but not both, and “2” for participation in both a fall and a spring sport.

Data Analysis

Each research question will be addressed separately.

The first question asks if the score on the national AP Calculus exam be predicted by the placement test score, midterm exam grade, and final course grade, or by some combination of these three factors? And, if these factors can predict the exams core, then what is the unique contribution of each of these factors in the prediction?

First, an ANOVA will be used to determine if the regression model gives a useful result. If so, the multiple regression equation would then be determined. Additionally, the unique contribution of each predictor will be determined.

The second question asks if there is an association between achievement on the national AP Calculus per gender, ethnic minority status and grade level? Chi-square tests for association and interaction of factors will be conducted. Using three grade levels, sophomore, junior and senior, resulted in multiple expected cell counts less than 5. Therefore, sophomores and juniors were combined into one category. This resulted in one cell with an expected cell count of 4.97, which is reasonably close to 5 to not reject the validity of the test.

The third question asks if achievement on the national AP Calculus exam varies according to participation in the arts and/or participation in sports? This calls for ANOVA.

Results

For the first question, the hypotheses are: H_0: $R^2 = 0$ versus H_a: $R^2 \neq 0$. The ANOVA results, shown in, Table 4, indicate that the model is significant for predicting AP exam score ($F(3,140) = 46.227$, $p < .001$). This provides evidence that the variance in AP exam scores which is accounted for by the three predictors does not equal zero.

The next step is to determine the least-squares regression equation and what percentage of variation in the dependent variable is explained by regression. From the model summary, Table 5, $R^2 = .498$, indicating that 49.8% of the variation in the students' AP exam scores are explained by the variation in their placement test scores, midterm exam scores, and final course grades. Using the unstandardized coefficients from the coefficients table, Table 6, the multiple regression equation is: $Y = 0.067X_1 + 0.051X_2 + 0.050X_3 - 6.714$, where X_1 is the score on the placement test, X_2 is the score on the midterm exam, and X_3 is the final course grade. Further, from Table 6, it can be concluded that:

(1) the AP exam score increases by .067 for every increase of one point on the placement test, if the two other variables are held constant.

(2) the AP exam score increases by .051 for every increase of one point on the midterm exam, if the two other variables are held constant.

(3) the AP exam score increases by .050 for every increase of one point for the final course grade, if the two other variables are held constant.

The statistical significance of the three regression coefficients for the individual predictors, placement test ($p = .010$), midterm exam ($p = .035$), and course final grade ($p = .033$), are all statistically significant at the 95% confidence level. This leads to the

question of individual contribution of each of the predictors. The Part correlations indicate that:

(1) for the placement test score, $r_y = .157$. So, approximately 2.5% of the variance in AP exam score is explained by the placement test score controlling for the midterm exam score and final course grade.

(2) for the midterm exam score, $r_y = .128$. So, approximately 1.6% of the variance in AP exam score is explained by the midterm exam score controlling for the placement test score midterm exam and final course grade.

(3) for the final course grade, $r_y = .129$. So, approximately 1.7% of the variance in AP exam score is explained by the final course grade controlling for placement test score and midterm exam grade.

For the second question, the hypotheses are:

H_0: There is no association between achievement on the national AP Calculus per gender, ethnic minority status and grade level.

H_a: There is an association between achievement on the national AP Calculus per gender, ethnic minority status and grade level.

Table 7 displays the cross-tabulation of gender versus AP exam score and the chi-square test results. One cell has an expected count of 4.97, which is reasonably close to 5 to not reject the validity of the test. Table 8 displays the cross-tabulation of ethnic minority status versus AP exam score and the chi-square test results. One cell has an

expected count of 4.58, which is reasonably close to 5 to not reject the validity of the test.

Table 9 displays the cross-tabulation of grade level gender versus AP exam score and the chi-square test results. Using three grade levels, sophomore, junior and senior, resulted in multiple expected cell counts less than 5. Therefore, sophomores and juniors were combined into one category, Table 10. This resulted in one cell with an expected cell count of 4.97, which is reasonably close to 5 to not reject the validity of the test.

We are unable to reject the null hypothesis with respect to ethnic minority status. We can conclude that there is no association between achievement on the national AP Calculus exam and ethnic minority status ($p = .234$). However, we can reject the null hypothesis with respect to gender ($p = .001$) and grade level ($p = .047$). It appears that girls perform better on the AP exam than do boys, across grade levels and ethnic minority status. Perhaps this is due to maturity levels, outside interests, or the fact that the AP Calculus teacher is female. This requires further investigation. It appears that older students (seniors) perform better on the AP exam than do younger students (sophomores and juniors). This is not terribly surprising. Even though a sophomore or junior who is enrolled in the course would have to be on the “fast track” in mathematics, that does not guarantee mastery of calculus. Perhaps, seniors are more aware of the necessity to have impressive transcripts for college admission. Again, maturity may play a role, as may motivation.

For the third question, Table 11 shows the results of Levene’s test for equality of error variances. The ANOVA assumption of equal variances is met ($p > .05$). Table 12

displays the test for between-subjects effects. The results for participation in the arts are F(1,138) = 6.489, p = .012, $p\eta^2$ = .045 (power .716). Results for participation in sports are F(2,138) = .761, p=.469, $p\eta^2$ = .011 (power .177). The partial eta-squared measure for the effect sizes for arts is .045, indicating that 4.5% of the variability in the students' AP exam scores can be explained by the percentage of students who participate in the arts, if all other factors and interactions of factors are controlled. The partial eta-squared measure for the effect size for sports is .011, indicating that 1.1% of the variability in the students' AP exam scores can be explained by the percentage of students who participate in sports, if all other factors and interactions of factors are controlled .

Because sports participation has three levels, a Tukey post hoc multiple comparison is also needed. This is shown in Table 13. This method pinpoints significant differences, if any exist, among the three levels of sports participation. Two of the pairwise comparisons are not statistically significant, For $\overline{Y}_1 - \overline{Y}_2$ (p = .341), the confidence interval (-.23, .91) contains zero. Similarly, for $\overline{Y}_1 - \overline{Y}_3$ (p = .700), the confidence interval (-.79, .39) contains zero.. However, for $\overline{Y}_2 - \overline{Y}_3$ (p = .027), the confidence interval (.05, 1.03) indicates that the mean AP exam score for students who participate in one sport is less than the mean AP exam score for students who participate in two sports by at least .05 and at most 1.03. This would seem to indicate the playing two sports helps to boost your AP exam score. Perhaps this is due to an association between physical activity and brain activity; or, perhaps, more gregarious students opt for more sports and more challenging courses.

Discussion and Conclusions

Multiple regression indicates that the AP exam score can be reliably predicted using the three predictors, at least for the sample data.

The chi-square analyses shows that there is no difference in AP exam achievement with respect to ethnic minority status; however, an interesting result shows that the girls in this study performed significantly better than the boys, even though they did not perform significantly better on the placement test ($p = .395$). The midterm exam and the final course grade each have over 20 possible values; so, analysis could not be completed without combining several levels.

Participation in sports ($p = .469$) and participation in both arts and sports ($p = .475$) are not statistically significant in the variation of AP exam scores. However, participation in the arts ($p = .012$) is statistically significant. One might expect that because (1) participation in sports involves leaving early for practices and games which frequently translates into missed classes, and, (2) late games mean that students may return home after 10:00 p.m. and have little time to attend to their studies. However, this does not appear to be a significant factor in AP exam results. Likewise, participation in the Arts can be time-consuming and interfere with academics. Practices for plays, musicals, and art shows are all time-intensive pursuits. This appears to have a significant impact on AP exam results.

Implications for Practice

The results are somewhat difficult to reconcile. It seems contradictory to accept that participation in sports has less of an effect on AP exam scores than does

participation in the arts. However, those students who participate in the arts may be less attuned to mathematics.

The idea that older students would generally do better on a national exam than would younger students is not surprising. The lack of differences in ethnic minority vs. ethnic non-minority achievement is not surprising because all data was collected from one independent (non-public) high school. No students at this school would be considered disadvantaged in any way. What is somewhat surprising is the girls doing better overall than the boys. This may well be a coincidence and when next year's data is added, it will be interesting to note if that association prevails.

It would be worthwhile to conduct similar studies at both public and private schools. Even if placement tests are not a significant factor, they are still worthwhile in placing students in the correct class. However, if the course grade is not a reliable predictor of the AP exam grade, then the teacher certainly needs to know that.

References

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Appendix

Table 1
Distribution of students in each grade level by gender

		Grade Level			
		Sophomore	Junior	Senior	Total
Gender	Male	7	31	41	79
	Female	6	21	38	65
	Total	13	52	79	

Table 2
Distribution of students by ethnic minority status and gender

		Ethnic minority status		
		Not Minority	Minority	Total
Gender	Male	43	36	79
	Female	41	24	65
Total		84	60	26

Table 3
Distribution of students by ethnic minority status and grade level

		Ethnic minority status		
		Not Minority	Minority	Total
Grade Level	Sophomore	7	6	13
	Junior	28	24	52
	Senior	49	30	79
Total		84	60	26

Table 4

ANOVA output for multiple regression of placement test score, midterm exam score and course final grade in predicting AP exam score

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	91.036	3	30.345	46.227	.000[a]
	Residual	91.902	140	.656		
	Total	182.938	143			

a. Predictors: (Constant), Course Grade , Placement Test , Midterm Exam Grade

b. Dependent Variable: AP Exam Grade

Table 5

Model summary for multiple regression

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.705[a]	.498	.487	.810

a. Predictors: (Constant), Course Grade , Placement Test , Midterm Exam Grade

Table 6
Multiple Regression Coefficients and Partial Correlations among Independent Variables Placement Test, Midterm Exam and Course Grade against Dependent Variable AP Exam Grade

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Correlations		
		B	Std. Error	Beta	t	Sig.	Zero-order	Partial	Part
1	(Constant)	-6.714	1.041		-6.451	.000			
	Placement Test	.067	.026	.218	2.620	.010	.589	.216	.157
	Midterm Exam Grade	.051	.024	.269	2.133	.035	.661	.177	.128
	Course Grade	.050	.023	.285	2.157	.033	.671	.179	.129

a. Dependent Variable: AP Exam Grade

Table 7
SPSS output with the chi-square test for association between gender and achievement on the AP exam

Gender * AP Exam Grade Cross-tabulation

			AP Exam Grade					
			Very Low	Low	Medium	High	Very High	Total
Gender	Male	Count	9	15	34	13	8	79
		Expected Count	6.0	9.3	31.8	17.6	14.3	79.0
		Std. Residual	1.2	1.9	.4	-1.1	-1.7	
	Female	Count	2	2	24	19	18	65
		Expected Count	5.0	7.7	26.2	14.4	11.7	65.0
		Std. Residual	-1.3	-2.0	-.4	1.2	1.8	
Total		Count	11	17	58	32	26	144
		Expected Count	11.0	17.0	58.0	32.0	26.0	144.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	19.918[a]	4	.001
Likelihood Ratio	21.518	4	.000
Linear-by-Linear Association	18.040	1	.000
N of Valid Cases	144		

a. 1 cells (10.0%) have expected count less than 5. The minimum expected count is 4.97.

Table 8
SPSS output with the chi-square test for association between ethnic minority status and achievement on the AP exam

Ethnic Minority * AP Exam Grade Cross-tabulation

			AP Exam Grade					
			Very Low	Low	Medium	High	Very High	Total
Ethnic Minority	No	Count	5	8	33	24	14	84
		Expected Count	6.4	9.9	33.8	18.7	15.2	84.0
		Std. Residual	-.6	-.6	-.1	1.2	-.3	
	Yes	Count	6	9	25	8	12	60
		Expected Count	4.6	7.1	24.2	13.3	10.8	60.0
		Std. Residual	.7	.7	.2	-1.5	.4	
Total		Count	11	17	58	32	26	144
		Expected Count	11.0	17.0	58.0	32.0	26.0	144.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.562[a]	4	.234
Likelihood Ratio	5.764	4	.217
Linear-by-Linear Association	1.341	1	.247
N of Valid Cases	144		

a. 1 cells (10.0%) have expected count less than 5. The minimum expected count is 4.58.

Table 9
SPSS output with the chi-square test for association between grade level (using three grade levels) and achievement on the AP exam

Grade Level * AP Exam Grade Cross-tabulation

			AP Exam Grade					
			Very Low	Low	Medium	High	Very High	Total
Grade Level	Sophomore	Count	2	0	10	0	1	13
		Expected Count	1.0	1.5	5.2	2.9	2.3	13.0
		Std. Residual	1.0	-1.2	2.1	-1.7	-.9	
	Junior	Count	1	6	21	15	9	52
		Expected Count	4.0	6.1	20.9	11.6	9.4	52.0
		Std. Residual	-1.5	-.1	.0	1.0	-.1	
	Senior	Count	8	11	27	17	16	79
		Expected Count	6.0	9.3	31.8	17.6	14.3	79.0
		Std. Residual	.8	.5	-.9	-.1	.5	
Total		Count	11	17	58	32	26	144
		Expected Count	11.0	17.0	58.0	32.0	26.0	144.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.721[a]	8	.047
Likelihood Ratio	20.032	8	.010
Linear-by-Linear Association	.144	1	.704
N of Valid Cases	144		

a. 5 cells (33.3%) have expected count less than 5. The minimum expected count is .99.

Table 10
SPSS output with the chi-square test for association between grade level (using two grade levels) and achievement on the AP exam

Crosstab

			AP Exam Grade					
			Very Low	Low	Medium	High	Very High	Total
Grade Level ADJ	Sopho-more or Junior	Count	3	6	31	15	10	65
		Expected Count	5.0	7.7	26.2	14.4	11.7	65.0
		Std. Residual	-.9	-.6	.9	.1	-.5	
	Senior	Count	8	11	27	17	16	79
		Expected Count	6.0	9.3	31.8	17.6	14.3	79.0
		Std. Residual	.8	.5	-.9	-.1	.5	
Total		Count	11	17	58	32	26	144
		Expected Count	11.0	17.0	58.0	32.0	26.0	144.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.207[a]	4	.379
Likelihood Ratio	4.286	4	.369
Linear-by-Linear Association	.158	1	.691
N of Valid Cases	144		

a. 1 cells (10.0%) have expected count less than 5. The minimum expected count is 4.97.

Table 11
Levene's test for equality of error variances

Dependent Variable: AP Exam Grade			
F	df1	df2	Sig.
2.296	5	138	.062

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Arts + Sports + Arts * Sports

Table 12
SPSS output for two-factor (sports and arts) ANOVA

Tests of Between-Subjects Effects

Dependent Variable: AP Exam Grade

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	17.208[a]	5	3.442	2.866	.017	.094
Intercept	807.860	1	807.860	672.690	.000	.830
Arts	7.793	1	7.793	6.489	.012	.045
Sports	1.829	2	.915	.761	.469	.011
Arts * Sports	1.816	2	.908	.756	.472	.011
Error	165.730	138	1.201			
Total	1763.000	144				
Corrected Total	182.937	143				

a. R Squared = .094 (Adjusted R Squared = .061)

Table 13
SPSS output for post-hoc test for sports

Multiple Comparisons

Dependent Variable" AP Exam Grade
Tukey HSD

(I) Sports	(J) Sports	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
No Sports	One Sport	.34	.241	.341	-.23	.91
	Two Sports	-.20	.250	.700	-.79	.39
One Sport	No Sports	-.34	.241	.341	-.91	.23
	Two Sports	-.54*	.207	.027	-1.03	-.05
Two Sports	No Sports	.20	.250	.700	-.39	.79
	One Sport	.54*	.207	.027	.05	1.03

Based on observed means.
The error term is Mean Square(Error) = 1.201.
*. The mean difference is significant at the .05 level.

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