Predicting Success in a Gateway Mathematics Course

Michael C. Morrison
President Emeritus, North Iowa Area Community College
6059 N. Elsie Road
Stone Lake, WI 54876
715-865-9717
Morrimic@niacc.edu

Shelly Schmit
Vice President
Institutional Effectiveness & Organizational Development
North Iowa Area Community College
500 College Drive
Mason City, IA 50401
641-422-4211
Schmishe@niacc.edu

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Abstract

A logit model predicting student outcomes for a gateway course, Math for Liberal Arts, was successfully developed which fits the data well. Two variables, ACT math score and high school GPA, were found to be significant predictors of achieving a C or better in Math for Liberal Arts. A practical implication of the study suggests that with just two pieces of information, a student’s high school GPA and his/her ACT math score, a counselor could input these two values into a spreadsheet and obtain the student’s predicted probability of success in Math for Liberal Arts.

Introduction

Gateway courses are extremely important for students to make adequate progress toward successful graduation. In order to meet higher expectations to compete in a global economy it is important for community colleges to develop strategies for improving the rate at which academically underprepared students take and pass initial college-level (or “gatekeeper”) courses. As the great majority of institutions of higher education require successful completion of general education courses it is vital for colleges to assess factors that may predict student success and use that information for counseling and placement in appropriate courses that maximize student potential for success.

This study examines the impact of important predictors of success in a gateway course in mathematics at North Iowa Area Community College. The odds and probabilities associated with the predictors of success in the gateway mathematics course are measured through a logistic regression analysis. While this is an institutional study the factors predicting student success in the identified mathematics gatekeeper course may well be common to many community colleges. Implications for appropriate placement based on success probabilities and odds are also examined.

Literature Review

It is a common practice for colleges and universities to identify students as under-prepared for a college-level course based on standardized placement scores (Kozeracki, 2002). A single measure alone has often been used to determine course level placement. A large body of research has focused on the analysis of ACT (American College Testing) scores. The cognitive factors that have been most widely considered as potential predictors of college mathematics achievement are the SAT (Standard Achievement Testing) and ACT scores (Benford & Gess-Newsome, 2006).

According to Golfin, Jordan, Hull, and Ruffin (2005), colleges generally require a score of at least 23 on the mathematical component of the ACT to be allowed to enroll in a college algebra class. Duranczyk and Higbee (2006) revealed that only 41% of students graduating from high school in 2005 scored a 22 or higher on the ACT math test, indicating they had a high probability of succeeding in college algebra. That leaves a potential of 59% majority pool of incoming high school graduates whose low ACT math scores predict a less than favorable outcome in succeeding in mathematics gateway courses. Kozeracki (2002) revealed that 55% of community colleges reported that the number of students in developmental studies has increased over the previous 5 years. Several states; Arizona, Colorado, Florida, Oklahoma, South Dakota, Tennessee, and West Virginia, have established an ACT math score of 19 or 20 as the minimum score necessary for students to enroll in college-level mathematics courses.

Kohler (1973) determined that ACT math and composite score are significant predictors of grades in college algebra. Twenty years later, House

(1995) revealed that the ACT composite score is a significant predictor of grades in a variety of introductory college mathematics courses. Gussett (1974) determined there is a strong correlation between SAT total (math and verbal combined) score and the grades in freshman-level mathematics courses. Bridgeman (1982) revealed significant relationships between SAT math score and student achievement in college algebra and finite mathematics. Jenkins, Jaggars and Roska (2009) found a substantial proportion of students with high placement test scores did not take gatekeeper courses.

Findings from other studies have revealed that combining admissions test scores with high school performance data can be used to successfully predict grades in a variety of college math courses. Richards et al. (1966) posited that high school grades are good predictors of college math grades, especially when combined with ACT scores. Noble and Sawyer (1989) revealed similar results in six college math courses using a combination of ACT composite scores and high school GPAs (Grade Point Average). Benford and Gess-Newsome (2006) posited that students' high school GPA and ACT scores are good predictors of grades in gateway courses.

While several researchers have revealed that standardized test scores and high school grades are effective predictors of success in college mathematics, some researchers have revealed contrary findings. Haase and Caffrey (1983a, b) posited that high school grades were generally useless as predictors of grades in introductory mathematics courses, and that SAT and ACT score did not predict overall scholastic achievement in community college. Yellott (1981) conducted a study that revealed neither the ACT or results from the Mathematic Association of America's Placement Program predicted success in university level developmental mathematics courses. The Mathematic Association of America's Placement Program offers a collection of standardized tests which aid in the recommendation of course placement. Despite these contrary findings, the majority of researchers tended to agree that standardized test scores and high school grades are effective predictors of success in mathematics courses.

Some research studies investigated more comprehensive approaches to devising placement standards. Lewallen (1994) used multiple measures to determine placement of students in courses. Variables examined to determine a relationship with course success were: age, high school grade point average, high school completion status, recency of formal schooling, years of high school math and grade in last math course, highest level of math class completed, recency of last math class, and units planned and work hours planned. Leweallen concluded that course success was strongly associated with high school grade point average, highest math class completed, grade in last math class, units planned, and recency of school. Illich, Hagan, and McCallister (2004) conducted a study of students enrolled in remedial courses along with regular college courses and concluded there are potential problems in predicting success when one relies on only one measure (e.g., standardized placement tests) to assess the preparatory needs of students. Their results were consistent with other findings indicating that student dispositional data better predict academic performance than standardized placement tests. Using standardized tests does not take into consideration a student's motivation to learn.

Felder, Finney, and Kirst (2007) conducted a study at American River College in California where the majority (90%) of students who began with a developmental [i.e., mathematics] course did not pass a transfer-level course. In 2004, American River College replaced traditional placement with an "informed self-placement" model for mathematics courses. Instead of placing students into courses based on test scores, self-placement is designed to match American River College math course content. Students take the level of math test they perceive best matches their skill level, and receive computer results immediately following the test. Counselors use the self-placement test results to advise students for appropriate course selection. Prior to the self-placement process, American River College relied on COMPASS test scores to determine math course placement. While the results from COMPASS and the self-placement assessment are similar, faculty and administration favor the self-placement assessment tool primarily due to the flexibility of the instrument and its cost. Whereas COMPASS is a fixed exam that must be purchased from ACT, faculty and counselors are able to customize the self-placement instrument (e.g., make updates and additions) to best fit each student's needs.

Several researchers have revealed that subject-specific placement exams written and administered by the same institutions that taught the math courses are the best predictors of student performance (Bone, 1981; Crooks, 1980; Helmick, 1983; Schultz & Austin, 1987).

In a study of 73 underprepared mathematics students Rochester Community College, Mercer (1995) revealed that students who followed the counselor's advice and were placed in a developmental mathematics course based on skill assessment scores were more likely to pass the entry college level mathematics course. This finding indicates that a developmental course can successfully prepare the student for a college level mathematics course.

A study was conducted at Cottey College, Missouri, to determine why a large number of students were dropping basic algebra and calculus classes (Callahan, 1993). The study focused on predictive variables, specifically standardized test scores, for success in basic algebra. Recommendations were made based on the finding of this study. For students with four years of high school math, the ACT score was considered for appropriate course placement. Students with only one year of high school math, and many with two or three years but test scores below 18 ACT and 400 SAT, would benefit from Intermediate Algebra. Within two years of establishing the program based on the study recommendations, the college saw improvements in mathematics course pass rates (Callahan, 1993).

The complexity of the published work supports the necessity to conduct site specific research with frequent reevaluations (Mercer, 1995).

Purpose

The purpose of this study is to conduct site specific research to predict success in a gateway mathematics course at North Iowa Area Community College. Based on the literature review and availability of data we posit three variables impact the odds of success in the gateway course. These three variables are ACT math score, high school GPA and number of high school math courses taken.

Data

The data for this study was obtained from an analysis of students enrolled in a gateway course, Math for Liberal Arts, during the 2006-07 college year at North Iowa Area Community College. Complete information on high school GPA, ACT math scores, number of high school math courses taken and success in Math for Liberal Arts was obtained for 275 students. The variables in this analysis are summarized in Table 1:

Table 1

Variable Names, Description and Coding

Variable Names	Description	Coding
Math_Success	A 'C' or better as a final student grade in Math for Liberal Arts	Dummy coded: 1 = Success 0 = Not successful
ACTM	Student ACT math score	Reported by ACT
HSGPA	Student high school grade point average	Reported from high school
NUMB	Number of high school math courses taken by student	Reported from high school

Research Hypotheses

The following null and research hypotheses were tested:

H_0 - Math_Success is jointly independent of the predictors, ACTM, HSGPA and NUMB, simultaneously; H_o: $\beta_1 = \beta_2 = \beta_3 = 0$.

H_1 - ACTM, HSGPA and NUMB independently and simultaneously effect Math_Success.

Research Methods

Logistic Regression. As the dependent variable, Math_Success, is a binary categorical variable and because we are interested in controlling for important variables that impact the odds of math success the analytical tool of choice is logistic regression. Logistic regression is "the most important model for categorical response data" (Agresti, 2002, p.165).

Logistic regression applies maximum likelihood estimation after transforming the dependent into a logit variable (the natural log of the odds of the dependent variable, Math_Success, occurring or not). In this way, logistic regression estimates the probability of success in Math for Liberal Arts, controlling for important predictor variables.

Findings

Characteristics of the Sample. The sample split for students who succeed versus those who did not succeed in Math for Liberal Arts is identified in Table 2.

Table 2

Sample Split Accelerated and Non-Accelerated Students

Group	N	Percent
Succeeded	137	49.82
Did Not Succeed	138	50.18
Total	275	100.00

Table 2 indicates that the sample is evenly distributed for those that succeeded versus those who did not succeed in Math for Liberal Arts. Table 3 depicts descriptive statistics for the variables of this study.

Table 3

Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Math Success	0.49	0.50	0.00	1.00
ACTM	18.43	2.86	13.00	28.00
HSGPA	2.68	0.58	1.09	3.89
NUMB	4.16	1.36	0.00	8.00

Logit Model for Math Success

The specified logit model has three predictors of Math_Success:

- ACT math (ACTM)
- High school gpa (HSGPA)
- Number of high school math courses taken (NUMB)

The logit model is formally expressed as follows:

$$\mathrm{Prob}(Math\_Success = 1 \mid (x)) = \lambda(\alpha + \beta_1 ACTM + \beta_2 HSGPA + \beta_3 NUMB)$$

where $\lambda(\cdot)$ is the logit function, $\exp(x)/(1+\exp(x))$, α is the constant and β_i represent logistic coefficients for each predictor variable. The effects can be simply stated as the odds ratio.

All statistical analyses were conducted utilizing Stata version 11 and SPost (Long & Freese, 2006). The logistic model specified above produced the following results.

Table 4

Logistic Regression Parameter Estimates

	Coef.	Std. Err.	*Z*	P>*z*	[95% Conf	Interval]
ACTM	0.13	0.057	2.32	0.021	0.020	0.244
HSGPA	1.87	0.299	6.23	0.000	1.280	2.456
NUMB	-0.09	0.107	-0.89	0.376	-0.304	0.115
_cons	-7.04	1.205	-5.84	0.000	-9.406	-4.682

Note. Likelihood-ratio (LR) = 71.84 with 3 df; p=0.000
Naglekerke's R-square = 0.308

The model appears to be significant but it is observed that NUMB, the number of high school math courses taken, is not significantly different from zero, p=.376. As such, we drop this variable from the analysis and recast the model as follows:

$$\text{Prob}\left(Math\_Success = 1 \mid (x)\right) = \lambda\left(\alpha + \beta_1 ACTM + \beta_2 HSGPA\right)$$

The revised logistic regression produced the following parameter estimates (Table 5) and odds ratio estimates (Table 6).

Table 5

Logistic Regression Parameter Estimates

	Coef.	Std. Err.	*Z*	P>*z*	[95% Conf.	Interval]
ACTM	0.12	0.057	2.25	0.024	0.0167	0.239
HSGPA	1.83	0.294	6.23	0.000	1.253	2.404
_cons	-7.26	1.20	-6.07	0.000	-9.604	-4.914

Note. Likelihood-ratio (LR) = 71.84 with 2 df; p=0.000
Naglekerke's R-square = 0.307
Hosmer-Lemeshow Statistic = 8.41 with 8 df; p= 0.395

Table 6

Odds Ratio and Estimates

	Odds Ratio	Std. Err.	*Z*	P>*z*	[95% Conf.	Interval]
ACTM	1.137	.065	2.25	0.024	1.017	1.270
HSGPA	6.228	1.828	6.23	0.000	3.503	11.0707

Interpretation

Model Interpretation. Table 5 reveals the revised logit model is statistically significant. The reported likelihood-ratio (LR) tests that Math_Success is jointly independent of the predictors simultaneously; H_o: $\beta_1 = \beta_2 = 0$. The LR test statistic of 71.84 is chi-squared (χ^2) with 2 degrees of freedom and a p-value of 0.000. This demonstrates strong evidence that at least one predictor has an effect on Math_Success. For a further test of the model's fit the Hosmer-Lemeshow statistic was estimated at 8.41 with 8 df; p= 0.395. This probability value indicates the model fits well.

Nagelkerke's R-square (0.31) is an attempt to imitate the interpretation of multiple OLS R-square based on the likelihood. Nagelkerke's R-square can vary from 0 to 1.

Interpretation of Coefficients. Table 5 also reveals that each predictor passes the Wald test indicating both predictors are significant. Nevertheless, it is known that logistic coefficients may be found to be significant when the corresponding correlation is found to be not significant, and vice versa. To make certain statements about the significance of an independent variable, both the correlation and the logit should be significant. This additional test was completed, confirming the statistical significance of the predictors.

All coefficients are large relative to their standard errors and therefore appear to be important predictors of Math_Success. However, the interpretation of logit coefficients is quite different from ordinary least squares. The logit coefficient indicates how much the logit increases for a unit of change in the independent variable, but the probability of a 0 or 1 outcome is a nonlinear function of the logit. It is, therefore, more useful to turn to an evaluation of "odds ratios".

Odds Ratio Interpretation. The odds ratio table provides a more intuitive and meaningful understanding for the impact of each predictor on

Math_Success. Table 6 reports odds ratio estimates for predictor variables as well as their standard errors and confidence intervals.

High School GPA. Given a logit coefficient, β_i , the odds ratio can be calculated $\exp(\beta_i)$. For example, the logit coefficient for HSGPA equals 1.83. The odds ratio equals exp(1.83) = 6.23. Holding ACT math scores constant, a one unit increase in high school GPA improves the expected odds for success in Math for Liberal Arts by a factor of 6.23.

Statistical significance of HSGPA has already been established but "*confidence intervals are more informative than tests"* (Agresti, 2002:172). Table 6 provides confidence intervals for each predictor variable. The confidence interval around the estimated HSGPA odds coefficient would capture the true value 95% of the time if repeated samples were drawn.

It is also useful to calculate the effect of changing a predictor by one standard unit and observe its impact on the dependent variable. If HSGPA increases by one standard deviation (0.58) we estimate the expected odds of success in Math for Liberal Arts improve by a factor of 2.89, $e^{[(1.83)*0.58)]} = 2.89$.

ACT Math. The odds ratio for ACTM is 1.14, signifying that each unit increase in ACTM produces a multiplicative 14% increase in the expected odds for math success, holding constant HSGPA.

We may say that when ACT Math increases one unit, the odds that math success = 1 increases by a factor of 14%, when HSGPA is held constant at its mean.

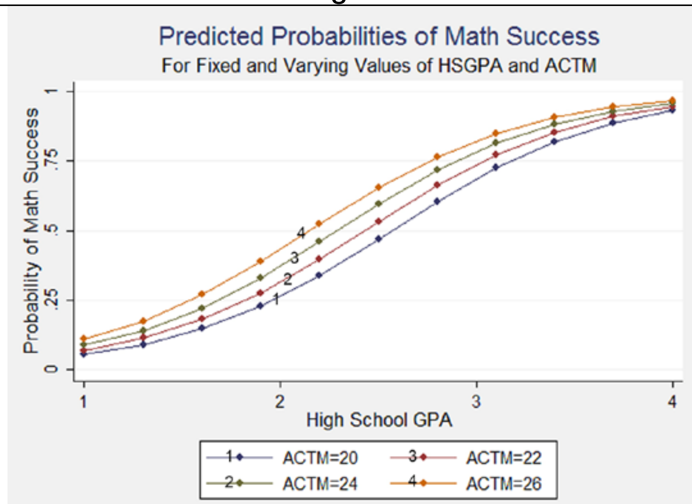
Holding HSGPA constant, an ACTM increase of one standard deviation unit (2.83) the odds of math success increases by a factor of 40%, $e^{[(.12)*2.83)]}=1.40$.

Clearly, in terms of impact HSGPA has a much greater effect on Math_Success than ACTM. We confirm this conclusion as we interpret the effect of both predictors on the probability of Math_Success in the next section.

Interpretation of Probabilities

Odds and probabilities are not equivalent. As such this section will identify the effect of the predictors on the probability of Math_Success. We begin by graphically depicting in Figure 1 the association of probability for Math_Success for fixed and varying levels of HSGPA and ACTM.

Figure 1 Probability of Math Success
Focus on High School GPA

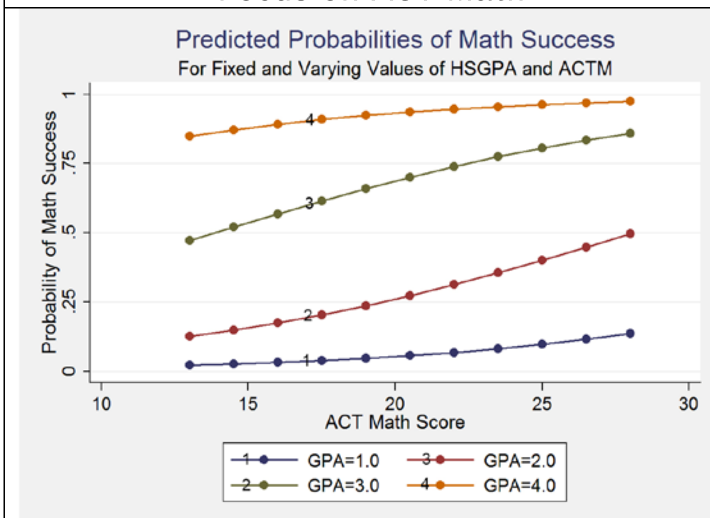


The above figure demonstrates the positive, direct effects of HSGPA on the probability of Math_Success at various levels of ACTM. ACTM appears to have less of an influence at the tails of HSGPA with larger impacts in the middle range of HSGPA. Students with an average 2.5 HSGPA with an ACTM score of 20 could expect a .47 success probability while students with ACTM score of 26 could expect a .66 success probability.

Figure 2 provides an informative perspective of the influence of ACTM on probabilities of Math_Success for fixed and varying levels of HSGPA and ACTM. While a positive relationship exists for ACTM’s influence on Math_Success at all levels of HSGPA it is clear the effect of ACTM on Math_Success is not as large when compared to the effect of HSGPA observed in Figure 1.

This observation is consistent with ACTM’s lower logit coefficient and odds ratio values when compared to respective HSGPA values in Tables 5 and 6. The slopes of the lines for GPA=1.0 and GPA= 4.0 in Figure 2 are much flatter than corresponding slopes associated with GPA=2.0 and GPA=3.0. HSGPA appears to overcome poor ACTM scores, witness the probabilities for Math_Success for students with low ACTM scores but high HSGPA scores.

Figure 2 Probability of Math Success
Focus on ACT Math



An informative method of demonstrating probability effects is to identify ‘different types’ of students and measure through probabilities the effect of their characteristics on Math_Success. We identify three types of students using ACTM and HSGPA scores: 1) those that have high favorable inputs 2) those that posses low inputs, and 3) average students.

Students with high favorable inputs are identified as those with an ACTM score of 24 and a HSGPA equal to 3.5. Students with low unfavorable inputs have corresponding values of 16 (ACTM) and 1.8 (HSGPA). We also include a category for students who have sample mean inputs (average students). The associated probabilities for success in Math for Liberal Arts for these three categories of students are provided in the following table:

Table 8

Probability of Math Success for Students with Varying ‘Inputs

	Probability of Math_Success	[95% Conf.	Interval]
High Input Students (ACTM=24 & HSGPA = 3.5)	0.902	0.833	0.970
Students with Average Inputs (ACTM=18.48 & HSGPA=2.68)	0.503	0.429	0.565
Low Input Students (ACTM=16 & HSGPA = 1.8)	0.128	0.615	0.194

The above table demonstrates that *“inputs count”*. Students with high inputs have a .90 probability of math success. On the other hand, students with low inputs have only a .13 probability of math success. The absolute difference in math success probability for students with high versus low favorable inputs is an astounding .77. Table 8 also reveals average students have approximately a 50-50 chance for success in Math for Liberal Arts.

Conclusions

A logit model predicting student outcomes for a gateway course, Math for Liberal Arts, was successfully developed which fits the data well. Two variables, ACT math score and high school GPA, were found to be significant predictors of achieving a C or better in Math for Liberal Arts.

Holding ACT math scores constant, a one unit increase in high school GPA improves the expected odds for success in Math for Liberal Arts by a factor of 6.23. Students with high inputs (those with an ACTM score of 24 and a HSGPA equal to 3.5) have a .90 probability of math success. On the other hand, students with low inputs (ACT math score of 16 and 1.8 high school GPA) have only a .13 probability of math success. Average students (ACT math score of 18.48 and high school GPA of 2.68) have a 50-50 chance of getting a C or better in Math for Liberal Arts.

An increase in ACT Math score by one unit increases the odds for math success by a factor of 14%, when HSGPA is held constant at its mean. An examination of logit coefficients, odds and probabilities indicates that high school GPA has a stronger effect on success in Math for liberal Arts than ACT scores.

Practical Implications

With two pieces of information, a student's high school GPA and his/her ACT math score, a counselor could input these two values into a spreadsheet and obtain the student's predicted probability of success in Math for Liberal Arts. For example, assume a counselor is meeting with a student and has the student's HSGPA and ACTM scores, 2.01 and 16, respectively. Entering these two values into a spreadsheet produces an expected probability of success of .18.

Table 9

Counseling Students for Math for Liberal Arts

Description	Measure
Enter Student High School GPA	2.01
Enter Student ACT Math Score	16.00
Probability of Earning a C or Better	0.18

As depicted in Table 9 we have produced such a tool. Given the relatively low probability of success in the given example the counselor could provide advice for the student to enroll in a preparatory course or supplementary instruction. This tool may be downloaded at http://www.niacc.edu/admin/pres/Presentations/Statistics/Counseling for Math for Liberal Arts.xls. The Excel spreadsheet is easily customized to another college providing the college has completed a logistic regression with the requisite coefficients.

In addition to the above counseling tool we believe another practical application of the analysis suggests that the college should continue to work with its regional middle and high schools seeking to improve degree completion rates for all students. Sharing the analysis with key stakeholders (faculty, students and parents) may provide the incentive for implementing policies and practices leading to continuous quality improvement.

Recommendations

It is impossible to predict with exact preciseness success of a student in any academic pursuit. We can use data to make strong predictions of success. As with anything, there will be students who defy predictions. Using predictive data will help to place a student in the class appropriate for their level of academic preparedness. The desired outcome of appropriate course placement will reduce student frustrations and improve persistence to graduation rates.

The current practice at NIACC of using the ACT math score for placement has been studied and proved to be a reliable predictor of success. Valid predictions for success would improve if the College also began to use high school GPA in concurrence with ACT math scores. The results of this study show a stronger correlation to success in the course Math for Liberal Arts with the high school GPA. Use of the ACT math and high school GPA to compute probabilities of success would provide an increased prediction of success.

It is recommended that NIACC continue the practice by student services personnel of relying on the ACT math score for placement in the course Math for Liberal Arts. It is further recommended student services personnel incorporate the use of high school GPA in course placement criteria.

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