Using Advising and Enrollment Data to Inform a First-Year Math Placement Program

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Abstract

We report on a three-year project to make data-driven improvements in the mathematics placement process at the University of Northern Colorado. We began by analyzing fall 2007 placement recommendations for a sample of N=1466 first-year students to the university. These recommendations came from brief faculty-student interviews during summer orientation sessions in which math instructors suggested one or more courses for students based on their most recent mathematics course and grade, high school grade point average, ACT math score, college major, and other information. We compared these recommendations to advising and enrollment data over the subsequent year, and, using logistic regression modeling, identified the background variables that best modeled success in students' first mathematics courses. This led us to make changes in the math placement process for summer 2009. We describe the new placement guidelines and summarize preliminary findings from a follow-up study on the impact of the changes.

Keywords: math placement, advising, first-year college math

By the mid-1990s, about 90% of postsecondary institutions used some method of placing students in their first mathematics course (Sawyer, 1996); however, methods for first-year mathematics placement includes tests, interviews, ACT or SAT scores, prior mathematical coursework, high school grade point average, or combinations of these and related data, but placement exams are perhaps the most common tool (Britton, Daners, & Stewart, 2007). Dorner and Hutton (2002) found that in the fall of 2000 nearly 1600 institutions of higher education used one of three competing commercial placement exams offered by the Mathematical Association of America, College Board, and ACT. Placement exams may be popular in part because they can be tailored to reflect prerequisite content requirements; however, several researchers have found that using a placement exam together with ACT-Math or SAT-Math scores, high school grade point average, and/or high school math courses and grades allows better prediction of success in a first mathematics course than an entrance exam alone (delMas, 1998; Dorner & Hutton, 2002; Klein, 2007; Latterell & Regal, 2003; Schumacher & Smith, 2008). Cotter (2007) conducted an in-depth study of placement processes finding placement tests less effective. He compared using the SAT test score and the students' best guess, the COMPASS test score with advice from a professor, and the COMPASS test prescriptively, finding that adding faculty advice yielded statistically significant improvement in success rates and potentially benefited student retention. Additionally, Cotter (2007) found that high school GPA did a better job than COMPASS at measuring pre-entry characteristics.

To inform mathematics placement at the University of Northern Colorado, we used a cyclical data-driven approach that involved investigating the relative importance of several variables in predicting the success of first-year students and using those results to making changes to the advising process.

Incoming students at the University of Northern Colorado participate in an interview-based mathematics placement process. During new student orientation, about 1,500 first-year and transfer students attend one of about 12 mathematics advising sessions. The leader of these 45-minute sessions, which typically include 100-200 new students and 5-7 mathematics advisors, engages new students in a discussion of some strategies for success in mathematics classes at the university such as forming study groups, attending class regularly, taking advantage of free tutoring services, and visiting instructors during office hours. Each student completes a brief background survey and then meets with one of the mathematics advisors – typically a graduate student or instructor in the School of Mathematical Sciences – who then recommends one or more mathematics classes to fulfill major or general education mathematics requirements for the student. Though this face-to-face approach to mathematics placement replaced a placement exam in the mid-1990s, the outcomes of the placement process had not been reviewed and faculty expressed lingering questions about the success rates of students in their first mathematics class at the university.

Beginning in the summer of 2007, and continuing for three years, we underwent a data-driven review of our mathematics placement process to (a) better understand factors associated with students' success in their first mathematics class at the university, and (b) initiate changes to the background survey and advising guidelines. Following a review of literature and discussions with faculty in the department, we defined *success* for a student as obtaining a letter grade of C or better in their first math class at the university and established the benchmark for successful mathematics placement at 80-90% overall success rates among new students. In the sections that follow, we describe how an initial study of success rates using advising, enrollment, and grade

data informed recent changes to the advising forms and guidelines, and report some preliminary indications of success rates following the recent changes.

Readers interested in the transferability of our findings regarding success rates and outcomes of first-year advising recommendations will need to consider the setting. The University of Northern Colorado is a mid-sized doctoral granting university in the Mountain West with a fall 2009 undergraduate enrollment of about 10,000, including about 2,400 freshmen. The university has origins as a liberal-arts school that specialized in the preparation of K-12 teachers, and elementary education remains the most popular major of incoming students. Admission records indicate 63% of students are female, 85% of students self-identify as Caucasian, and over 90% of students are under 25 years of age. Though about one-quarter of incoming students have not chosen a college major, over 95% select a major by the end of their first year. Common majors of students at the end of their first year include elementary education (14%), business or marketing (14%), health sciences (11%), communications/journalism (10%), parks and recreation (7%), psychology (7%), social sciences (7%), and visual/performing arts (7%). First-semester mathematics classes are typically taught by graduate students in the School of Mathematical Sciences Ph.D. program in Educational Mathematics or by adjunct instructors.

Summer 2007 began of our review of the mathematics advising process at the university. Incoming students completed a background survey with 14 items: name, date, student ID number, major, ACT Math or SAT Math score, ACT English or SAT Verbal score, free response "most recent mathematics class" with (a) "taken in" (high school or college) designation, (b) semester and year when the course was taken, and (c) grade in the class, overall high school grade point average, number of planned first-semester college credits, and number of weekly hours planned for working at a job. (For more details, see Fitchett, King, & Champion, in press.)

The free-response format of the most recent mathematics class required mathematics advisors to have specialized knowledge of the many high school mathematics course titles, and students often had difficulty estimating their planned weekly work hours (often replying “not sure”).

Mathematics advisors were instructed to consider all the data on the advising form, and to ask students questions about their background and/or preferences for a first mathematics class when appropriate. Most importantly, advisors closely followed required mathematics classes from the academic catalog descriptions of majors. In cases where major requirements indicated any general education mathematics course, advisors followed specific guidelines on ACT Math scores in conjunction with the perceived sophistication of the students’ recent high school mathematics class. The remaining advising form data was used inconsistently during the brief face-to-face advising interviews, typically as contextual information for students with an undeclared major or marginal ACT scores and recent mathematics grade.

Initial Study of Placement Outcomes

The studies reported here address two cyclical research questions: (1) What background variables available in the mathematics placement process best model student success in first year mathematics courses?, and (2) What are the impacts of data-driven changes made to the math placement process in terms of advising recommendations and student success rates?

Using summer 2007 advising forms and 2007-2008 course enrollment and grade data for a sample of 1,466 students, we found 73% (1,068) of first-year students took a mathematics class in their first year, with an overall success rate of 75.8% (810/1,068). Success rates were almost identical in the fall (78.4% of 732) and spring semesters (78.3% of 336), but students who took a recommended class had a slightly higher success rate than those who enrolled in a non-recommend class (80% versus 72%, respectively, $\chi^2(1)=8.1$, $p<0.01$, $\Phi=.09$). As shown in Figure

1, success rates in the four largest enrollment courses ranged from 75.6% (Mathematics and Liberal Arts) to 93.1% (Number and Operations for Elementary Teaching Majors). The class with the lowest success rate during the first year was Intermediate Algebra, with just 41.7% (15/36) of students who enrolled in the class passing it on the first attempt.

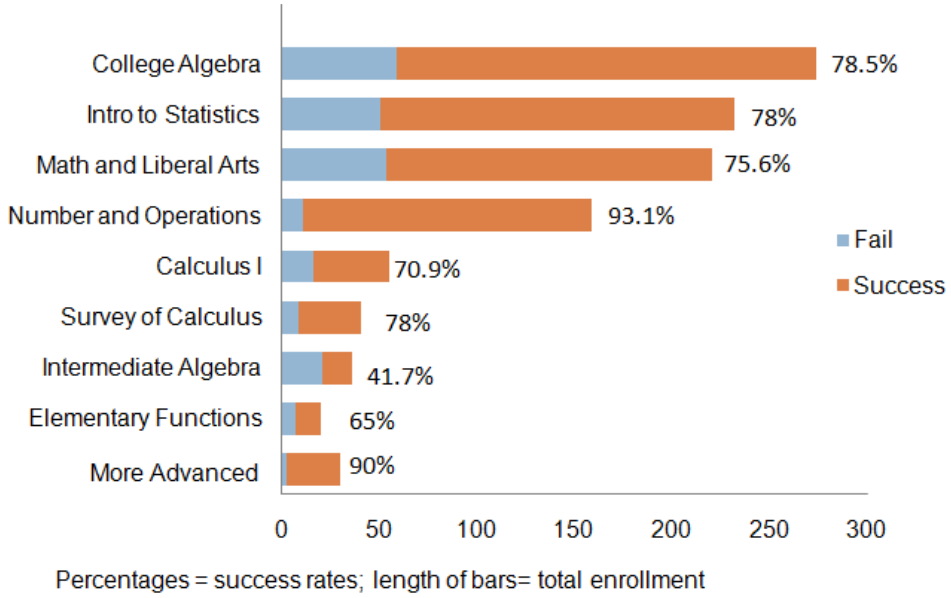

Figure 1. First math course enrollment and success rates by course.

Our descriptive analyses of success rates by each of the variables on the background survey focused on three background variables: the students' most recent mathematics class prior to coming to the university, letter grade in that course and ACT Math score. Success rates by recent high school mathematics courses varied, with students who reported calculus as their most recent mathematics course experiencing the highest success rate (93% of 130), followed by pre-Calculus (83% of 332), Statistics (81% of 14), Algebra II (72% of 272), Trigonometry (71% of 95), and other (60% of 85). Students' reported letter grades in these recent classes showed a consistent positive association with success in the students' first mathematics class at the university: success rates were highest for students whose most recent grade in mathematics was

an A (88% of 244), followed by those with a B (82% of 413), C (72% of 292), D (64% of 77), and F (50% of 16).

With indications of variables associated with success rates from descriptive analyses, we addressed the first research question (on background variables that best model success in a first mathematics class) by using logistic regression with success (pass or fail) as a function of our various predictor variables: most recent math course taken, letter grade in that course, high school GPA, Math ACT, whether or not the student enrolled in a recommended course, and which semester the first college math course was taken (fall or spring). In our initial logistic regression analysis of success in first math course, we fit all 64 possible models (including or excluding each of the 6 explanatory variables) and used the AIC criterion (Akaike, 1976) for model selection. Overall, the best-fitting model included the most recent math course taken, the grade in that course, high school GPA, and whether the course was recommended or not. Neither ACT math scores nor the semester the first course was taken was useful in modeling success in the students' first mathematics class.

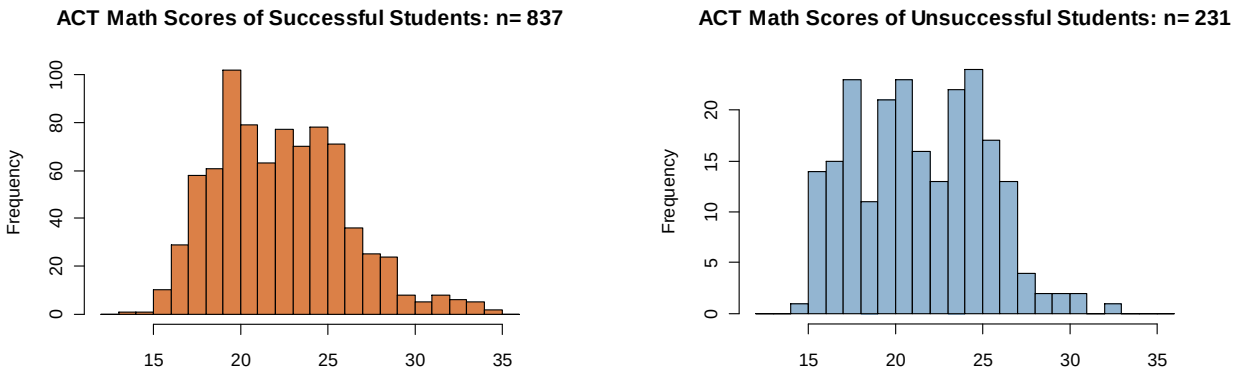

Figure 2. Histograms of ACT-Math scores of successful and unsuccessful students.

High school GPA had by far the largest effect on the odds of success, with a 1 point increase in high school GPA corresponding to a predicted increase of a factor of approximately 7.4 in the odds of success, when all other variables were held constant. Considering the

variability in success rates by course (Figure 1) and relatively large sample, we also performed logistic regression analyses of success in the three most common courses – Mathematics and Liberal Arts, College Algebra, and Introduction to Statistics. The findings from these within-course models supported the overall findings (Table 1), further supporting the importance of high school GPA and recent mathematics course grades as variables most associated with success rates in first mathematics courses.

Table 1.
Significant Variables in Logistic Regression Models for Success by First Course

College Course	Recent Course	Recent Grade	HS GPA	Math ACT	Followed Rec.	Term
Liberal Arts		X	X	X		
College Algebra	X	X	X		X	
Intro Stats		X	X		X	
All Courses	X	X	X		X	

Note. X = significant at the $\alpha = .05$ criterion in a logistic regression model of success.

Follow-Up Study on Changes to the Placement Process

The findings from the initial study prompted us to make changes to the background survey and advising guidelines for first-year mathematics placement. Beginning in summer 2009, first-year students completed a modified background survey (see the Appendix) that included several changes based on the data in the initial study, including a closed-response question in which students circled all prior mathematics courses from among a list developed from the open-response responses in the initial study and grouped into three tiers based on observed success rates from the initial study. In addition, students were invited to list any mathematics classes they were interested in taking (i.e., “Any preferences for your first math class at UNC?”), and disclose any college mathematics or statistics credits they may have earned

prior to coming to the university. Finally, the prompt asking for students' anticipated college major(s) included an "Undeclared, but maybe …" option.

During an organizational meeting of mathematics placement advisors prior to the summer 2009 placement sessions, the researchers described the logistic regression results from the initial study, the changes in the background form, and suggested several changes in the guidelines for making recommendations. These included (1) decreased emphasis on ACT Math scores, (2) increased emphasis on high school GPA and recent high school mathematics grades (with a B or higher indicating a higher chance of success), and (3) interpretation of the 3-tier classifications of high school mathematics coursework as indicating above average, about average, and below average success rates. In addition, instructors were encouraged to recommend Statistics (instead of College Algebra) for students with a major that did not specify a specific mathematics general education requirement and to recommend a local community college class for students in need of Intermediate Algebra. Students' intended college major, and associated catalog mathematics requirements, remained the most important single piece of background information during the advising process.

As part of our ongoing evaluation of the mathematics placement guidelines and students' success rates, we obtained student enrollment data and course grades for all first year students who took a mathematics class in their first semester (fall 2009) at the university. This, combined with the survey responses from a random sample of 705 advising forms, allowed us to develop preliminary indications of some outcomes of the modified advising form and advising guidelines. In particular, we were interested in whether success rates continue to support the variables identified as being most associated with success in a first mathematics class and whether recommendation and/or enrollment patterns aligned with the new advising guidelines.

Of the 41% of students in the sample who took a math class in fall 2009, all took a recommended class (compared to 83% of the students in the initial study). In addition, there were some indications that the mathematics placement recommendations may have changed based on the new advising guidelines. Though potentially due to changes in catalog requirements or the distribution of college majors (e.g., the university has recently seen increases in the number of criminal justice majors), Introductory Statistics replaced College Algebra as the most recommended course for students in the sample. Based on the first recommendations, Statistics was most common (25% compared to 13% in the initial study), followed by Math and Liberal Arts (19%), College Algebra (15%), Number and Operations (11%). In addition, just 3% of students received Intermediate Algebra as a first recommendation.

The overall success rates in the follow-up sample was 77.4% (223/288) among students taking a mathematics class in their first semester, which was similar to the success rate among the fall-enrolling students in the initial study (78.4%). However, as indicated by Table 2, success rates were higher than that observed in the initial study for Math and Liberal Arts, Introduction to Statistics, Math for Elementary, and Calculus I. That is, it seemed likely that the overall success rate remained similar to that in the initial study due in large part to a much lower success rate in College Algebra (59.7% versus 78.5% in the initial study). Some plausible sources for this observed decease in success rates in College Algebra might include (1) instructional variation, (2) an increase in students recommended into College Algebra who would have previously been recommended into Intermediate Algebra, and (3) catalog changes at the university level that may have changed the distribution of college majors among students taking College Algebra.

Table 2.
Success Rates by First Math Course in Fall 2009

First Math Course (*N* = 288)	Count	% Success
Math and Liberal Arts	69	82.6
Intro Statistics	63	84.1
College Algebra	62	59.7
Math for Elementary	36	97.2
Calculus I	29	75.9
Other	29	65.5

Following the indications from the initial study that recent mathematics classes were associated with varying success rates, we investigated the potential predictive validity of the 3-tier categorization of high school mathematics classes as an indicator of success rates. As given in Table 3, success rates within the tiers appeared to correspond well to the descriptions developed in the initial study – students with recent mathematics classes in Tier 1 had a below average success rate in their first college mathematics class (66.7%), and those in Tier 3 had a higher than average success rate. Interestingly, students whose most recent mathematics class was in Tier 1 had a much higher success rate in Math and Liberal Arts (27/33) than in College Algebra or Statistics (12/29). This suggested that students with less high school mathematics preparation might be best prepared for Math and Liberal Arts as their first college mathematics class. In addition, the relatively low success rate in College Algebra was consistent across the tiers of recent math, with students with Tier 3 preparation having just a 65% (19/29) success rate.

Table 3.
Success Rates by Most Recent Math Class in Fall 2009

Most Recent Math Class (N = 265)	Count	% Success
Tier 1 (General or Basic Math, Pre-Algebra, Geometry, Algebra I/II, Trigonometry)	75	66.7
Tier 2 (Integrated 1-4, TGA, Statistics, Prob & Stats, Discrete Math)	40	77.5
Tier 3 (Pre-Calculus, Calculus, AP Calculus, AP Stats, Diff Eq, College Algebra, Linear Algebra)	150	83.3

As in the initial study, we modeled success (pass/fail) as a function of background variables (including high school GPA, ACT Math scores, recent math grade, and the tier of recent math class) using logistic regression. However, only high school GPA exhibited significant effects on success rates ($p < .001$), with recent high school mathematics class approaching significance ($p = .08$). Due to the much smaller sample size in the follow-up study, and concomitant reduction in statistical power, we anticipated a reduced sensitivity in the logistic regression modeling to hypothesized association between background variables and success rates. Thus, we considered the logistic regression modeling results to be in line with our earlier findings, and we expected additional confirming or disconfirming evidence as we gather additional enrollment and advising data in future research.

Conclusion

We hope our experiences using advising, enrollment, and grade data at the University of Northern Colorado to inform changes to first-year mathematics placement can serve as a model for institutions interested in implementing mathematics placement procedures that do not rely solely on placement exams. We entered the longitudinal investigation of our mathematics placement process with several long-standing guidelines and procedures and the simple motive

of comparing our guidelines to enrollment and grade data. Using logistic regression and cross-tabulations, we identified several variables that could be better utilized as indicators of the chances a student will succeed in their first mathematics class at our university. These indicators, which included high school GPA as well as the tier of and letter grade obtained in recent high school mathematics coursework, led to a change in our advising guidelines. Though we have yet to obtain our overall goal of 80-90% success rates in first-year mathematics classes, we believe the cyclical data-driven process will help us get there soon.

Though we believe many contextual variables make findings from our study problematic at other universities – and we leave it to readers to compare and contrast their institution to ours – we believe there are several findings from our analysis of success rates that may transfer to other institutions. These include (1) increasing the emphasis on high school GPA and recent high school math grade in mathematics placement guidelines with ACT Math score as a secondary indicator, (2) encouraging students to follow advising recommendations, (3) suggesting either fall or spring terms for a student's first mathematics class, and (4) considering recommending statistics over college algebra for students with no specific mathematics requirement associated with their chosen major. Some implications for placement processes might include training undergraduate "team leaders" who can help with new-student registration, and the possibility of communicating placement guidelines through the university website and informational brochures to incoming students prior to placement. Since our research results were preliminary, we believe follow-up inquiry is needed, such as incorporating qualitative data from faculty, students, and "team leaders" involved in placement, measuring implementation of guidelines, considering the percentage recommendations not determined by major, and investigating the possibility of including a placement exam in conjunction with interview procedures.

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Appendix – Summer 2009 Advising Form

Please provide the following information for math advising. The School of Mathematical Sciences collects this information to help us advise you and to help improve the advising process for future students.

Name _____ Date _____

Bear # _____

College Major(s) _____ □Undeclared, but maybe _____

What best describes the math classes you completed in HIGH SCHOOL (or after)? (Circle ALL that apply.)

General Math/Consumer Math	Integrated Math 1 (IMP/CPM)	Pre-Calculus
Basic Math 1, 2, 3, or 4	Integrated Math 2 (IMP/CPM)	Calculus
Pre-Algebra	Integrated Math 3 (IMP/CPM)	AP Calculus (A/B)
Informal Geometry	Integrated Math 4 (IMP/CPM)	AP Calculus (B/C)
Geometry	Trig/Geom./Algebra (Combined)	AP Statistics
Algebra 1	Statistics	Differential Equations
Algebra 2	Probability & Statistics	College Algebra
Trigonometry	Discrete Math	Linear Algebra

☆Please put an asterisk (*) next to your most recent math class above.

When did you take your most recent class? (e.g., Spring 2009)_____
What was the letter grade in your most recent math class? (e.g., B+) _____

Overall High School GPA _____ ACT (or SAT) Math Score _____

Have you earned any college credits in math or statistics? YES NO if yes, in what class?

Any preferences for your first math class at UNC?

We Recommend: ☐Exempt from LAC

Preparatory	Intro LAC	Calc Prep w/ Trig	Calculus
MATH 023 Intermediate Algebra	MATH 120 Math & Liberal Arts	MATH 125 Plane Trigonometry	MATH 176 Topics in Calculus
MAT 106 (at AIMS) Survey of Algebra	STAT 150 Intro. Statistical Analysis	MATH 127 Elementary Functions	MATH 171 Calculus for Life Sciences
	MATH 124 College Algebra		MATH 131 Calculus I
	MATH 181 Fund of Math I (Num/Ops)		MATH 132 Calculus II