Delaying Developmental Mathematics: The Characteristics and Costs

By Marianne Johnson and Eric Kuennen

Educators do not understand well what makes a student likely to complete a developmental mathematics requirement in a timely fashion.

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ABSTRACT: This paper investigates which students delay taking a required developmental mathematics course and the impact of delay on student performance in introductory microeconomics. Analysis of a sample of 1462 students at a large Midwestern university revealed that, although developmental-level mathematics students did not reach the same level of performance as nondevelopmental microeconomics students, students who did take developmental mathematics performed better than students who had not yet done so. We recommend that students needing mathematics remediation take the course in their first semester and that the importance of developmental courses to other disciplines be stressed.

When required by a college or university mathematics placement exam to take developmental or remedial mathematics, what kind of students put off taking the course? And, for those who do, is their ability to succeed in other courses with a quantitative component—such as introductory microeconomics—affected by delay?

Many institutions in the United States devote significant resources to the teaching of developmental-level mathematics courses. The National Center for Education Statistics reports that 72% of colleges and universities offer developmental mathematics courses, and, nationwide, 24% of entering college freshmen are required to take developmental mathematics (Merisotis & Phipps, 2000). Given the level of debate over the provision of developmental course work at 4-year institutions (Artigue, 1999; Saxon & Boylan, 2001), it is important to quantify whether developmental-level courses make a difference in the ability of students to succeed in other college courses.

Previous research has identified student characteristics related to success in developmental-level mathematics. For example, age and ethnicity of students, as well as their enrollment status, are significantly related to performance in developmental mathematics and college algebra (Penny & White, 1998). However, educators do not understand well what makes a student likely to complete a developmental mathematics requirement in a timely fashion and the extent to which this decision influences academic performance in other courses.

One goal of developmental mathematics is to increase preparation of students with poor mathematics skills prior to taking mathematics courses necessary to meet university graduation requirements. This has been the focus of most previous studies which have evaluated developmental mathematics courses based solely on whether they build students' mathematics skills so that they are competitive with their peers in mainstream advanced mathematics courses (Hagedorn, Siadat, Fogel, Nora, & Pascarella, 1999; Hammerman & Goldberg, 2003; Merisotis & Phipps, 2000; Penny & White 1998; Wright, Wright & Lamb, 2002).

However, a second and perhaps more important goal of developmental mathematics is to develop students' ability to apply knowledge gained in one situation to solve problems in another, such as using mathematics skills in nonmathematics courses that have a quantitative, problem-solving, logical, or abstract component. Thus, our research focuses on whether developmental mathematics improves students' performance so that they are competitive in nonmathematics courses. Our review of the literature has found only one study in this area. (Grillo, Latif, & Stolte, 2001); it examines the influence of mathematics remediation in a pharmacology program.

Introductory microeconomics is a good candidate for this analysis because of the considerable research linking mathematical skills with student performance in economics. Studies have found that high ACT or SAT mathematics scores or taking calculus or business mathematics has a significant and beneficial effect on student grades in introductory economics (Anderson, Benjamin, & Fuss, 1994; Durden & Ellis 1995; Ely & Hittle 1990). Further, Ballard and Johnson (2004) have reported that mastery of very basic mathematics concepts—of the kind covered in developmental mathematics courses—are positively and statistically significantly related to student success in introductory economics.

Purpose

The purpose of this study is to identify the characteristics of students who delay taking developmental mathematics and examine whether this delay is associated with poorer performance in introductory microeconomics, a nonmathematics courses with a significant quantitative component.

Design and Methodology

Sample

In an observational study, we examine a sample of introductory microeconomics students at a large Midwestern university. Introductory microeconomics addresses supply and demand, consumer behavior in determining the demand for goods and services, the theory of the firm, production and costs, and theories associated with the distribution of goods and services throughout society. Introductory microeconomics instructors rely on student knowledge of graphing, slope, manipulating ratios, finding the area of basic shapes such as triangles and rectangles, locating the intersection of lines, and solving simple systems of linear equations. Introductory microeconomics is taken by a wide cross-section of students and is required for all business, journalism, communications, and social science majors. The course also meets a basic social science requirement and is often chosen by students in mathematics, engineering, and the sciences.

The sample includes students not required to take developmental mathematics, students who completed their developmental mathematics requirement, and students who have not yet completed their developmental mathematics requirement. A flowchart describing the student decision-making process when registering for courses is presented in Figure 1.

Data Collection

We examined four sections of introductory microeconomics taught in a large-lecture format by the same professor in consecutive class periods, two each during the Fall semester of 1998 and the Fall semester of 1999. Data were gathered in part using a voluntary survey instrument administered during the second week of class, containing 26 questions about demographic characteristics such as university class level, race, and gender, as well as questions about the student's study and work habits, motivation, and mathematics background. This was supplemented by university data on student grade point averages (GPA), ACT scores, score on the university mathematics placement exam, and mathematics course history.

Of the students surveyed, 41% were pursuing business majors, and over 77% reported that microeconomics was required for their major. In the sample, the mean ACT score on the mathematics portion of the exam was 23.07 (*SD* = 3.84). The majority of students (60.33%) had taken calculus or business calculus. Other student characteristics are summarized in Table 1.

Table 1
Summary of Student Characteristics and Mathematics Experience

Student Characteristics	Overall	Mathematics Experience			
		Developmental mathematics not required	Developmental mathematics required and taken	Developmental mathematics taken concurrently	Developmental mathematics required but not taken
All Students	*N* = 1462	*N* = 1112	*N* = 262	*N* = 28	*N* = 58
	100.0%	76.06%	17.92%	1.92%	3.97%
Gender					
%Male	52.19	53.14	55.34	60.71	63.99
%Female	47.81	48.86	44.66	39.29	36.79
Race					
%White	83.31	85.10	74.81	84.14	87.93
%Black	5.75	6.64	4.36	3.57	1.72
%Hispanic	1.71	1.26	13.36	7.14	5.17
%Asian	6.90	3.95	3.05	3.57	3.45
%Other	3.15	3.05	3.82	3.57	1.72
Class					
%Freshmen	19.15	20.47	4.58	39.29	50.00
%Sophomore	54.58	54.58	59.16	39.29	41.38
%Junior	21.41	19.84	31.30	21.34	6.90
&Senior	4.04	4.13	4.58	–	1.72
%Other	0.82	0.99	0.38	–	–
%English Not Native Language	5.81	5.92	6.11	7.14	1.72

Scores on three multiple-choice exams determined each student's grade in the course. These exams were identical in all sections within any given semester and highly similar across semesters. The average course grade was a C plus, or a 2.6 on a 4.0 scale (*SD* = 1.16). Out of the 2313 students enrolled in the four sections, the survey yielded a useable sample of 1462 students.

Mathematics Matriculation Data

At this institution, developmental mathematics is required for students who fail a mathematics placement exam by scoring 9 or fewer questions correct out of 28, or who score less than 12 on the ACT mathematics section. The average mathematics placement score for students placing into developmental mathematics is 7.78 (*SD* = 4.04) questions answered correctly on the exam, whereas the average score for nondevelopmental students is 14.14 (*SD* = 5.48). A low score on the placement exam is believed to indicate that the student's mathematics skills are deficient, meaning that the student failed to master concepts typically taught in high school algebra. Hence, without a developmental mathematics course, substandard mathematics skills are expected to hinder a student's ability to succeed in other university courses and meet graduation requirements.

The developmental mathematics course in our study is roughly equivalent to between

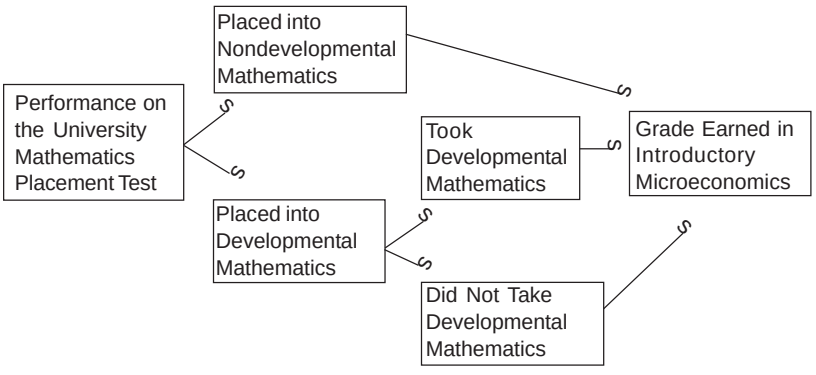

Figure 1. Flowchart exhibiting various patterns of student decision-making and course scheduling.

1 and 2 years of high school algebra, covering the properties of real numbers, operations on polynomial and rational expressions, properties of exponents, linear and quadratic equations, and some basic exponential and rational equations. Graphing calculators are used throughout the course. Multiple representations, such as verbal, tabular, graphic, and symbolic, are used to study the relationships embodied in the problems.

Of students in our survey, 23.94% were required to take developmental mathematics; this is slightly less than the 30% of students required to take developmental mathematics on average at this university. At the time of their enrollment in principles of microeconomics, 17.92% of the students in the subsample had taken their required developmental mathematics course, 1.92% of students were taking it concurrently, and 3.97% of students had not yet taken the course. As expected, from the subsample of students who placed into developmental mathematics, freshmen were the least likely to have completed their developmental mathematics requirement. In the overall sample, women were slightly more likely to be required to take developmental mathematics. Minority students were also more likely to have to complete a developmental mathematics requirement. Previous studies have found similar patterns (Siegfried, 1979; Stage & Kloosterman, 1995). Nearly a quarter of the sample had taken no mathematics at the university level.

Table 2
Grade Earned in Economics

Grade Earned in Introductory Microeconomics	Overall	Mathematics Experience			
		Developmental mathematics not required	Developmental mathematics required and taken	Developmental mathematics taken concurrently	Developmental mathematics required but not taken
Mean	2.61	2.70	2.32	2.43	2.41
SD	(1.14)	(1.12)	(1.21)	(1.20)	(1.34)
%A	17.37	19.30	9.54	14.29	17.24
%B+	16.69	16.97	15.65	14.29	17.24
%B	18.26	18.85	16.79	14.29	15.52
%C+	15.94	15.80	17.56	17.86	10.34
%C	13.61	13.76	13.74	14.29	10.34
%D+	5.68	4.76	8.02	10.71	10.34
%D	2.94	2.42	4.96	3.57	3.45
%F	9.51	8.17	13.74	10.71	15.52

Students who were not required to take developmental mathematics were more likely to earn high grades in their microeconomics course. Students who placed into developmental mathematics were more likely to fail economics, and students who delayed taking developmental mathematics had the highest failure rate of any group (see Table 2).

Limitations

We are missing observations for approximately 37% of the students enrolled in the course. Students who did not complete the course, did not properly fill out the survey, or may not have been in class on the day the survey was administered are missing from the sample. The fact that many students did not complete the survey is not surprising, as the class was taught in a large-lecture format and students received no grade for attendance. Therefore, we must address the issue of selectivity bias in our survey sample. The data suggest that the students absent from class on that day were likely to be poorer students: Those who took the survey had a mean of 73% of test questions answered correctly overall in the course, whereas those who did not take

NADE News: Emeritus Council Update

By Susan Hashway, Emeritus Council Chair

I have a coffee mug at home that is inscribed with, "Old Teachers Never Die, They Just Lose Their Class." It inspired me to request an update on Emeritus Council members. Although all of these people were highly visible when they were president of NADE, they haven't retired or lost their class since relinquishing their presidency. Hopefully, this will be the start of a regular column in "NADE News"!

Nancy Carriuolo is still involved in developmental education through the Rhode Island Office for Higher Education. The office is currently working on a definition of developmental education and a policy that can be used by the system in regard to developmental work. Over the summer she spoke as part of a panel on developmental education at a SHEEO (State Higher Education Executive Officers) conference in Philadelphia; Hunter Boylan was leader of the three-person panel. She still writes for and serves on the editorial board of the *JDE*.

David Arendale is entering the third year of his tenure-track assistant professor position at General College, University of Minnesota. He teaches World History Since 1500 and continues his research interests with the history of access and developmental education. He has embedded study strategy instruction within his history class and is working on developing an enhanced peer study program to support the class as well. He has a number of publications that have been accepted in this area and he continues to make conference presentations on the same topics.

Linda Thompson coauthored a Ronald E. McNair Postbaccalaureate Achievement grant proposal the year before last that was funded last year! Now she is directing a new program that works with first-generation, low-income students and students of color to prepare them for graduate studies. She describes her work as, "carrying Developmental Education to the other end of the spectrum, working with very capable students who are underrepresented in graduate education and helping them to aspire to and prepare for Ph.D. studies."

These former NADE leaders continue their support of the field subsequent to leaving office. Professional contributions of these and other colleagues impact the role of developmental education in higher education.

NADE: Helping underprepared students prepare, prepared students advance, and advanced students excel!

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the survey had a mean of 64%, a significant difference ($c^2 = 56.86$, $p < 0.001$). However, since the missing students are poorer students, and since poorer students have, on average, poorer mathematics skills, if we had the missing students in our sample, the estimations and results could actually be strengthened (Ballard & Johnson, 2004). In addition, we are missing some other important information as transfer students do not have ACT scores. Since we do not want to bias the data by dropping all transfer students, we follow Greene (2002) by estimating values for the missing ACT scores and using the predicted values for the 106 transfer students.

Analysis and Results

Initial Examination of the Data

Examination of the correlation coefficients between key mathematics variables indicates that mathematics skills are related to student performance in introductory microeconomics. Being required to take developmental mathematics is negatively correlated with performance in economics (r = -0.14), whereas higher ACT Math scores, having taken calculus, and higher scores on the university math placement test all have positive correlations (ranging from 0.14 to 0.25).

Who Delays Taking Developmental Mathematics?

We seek to understand which student characteristics are associated with a delay in taking developmental mathematics using multiple regression analysis and estimate the regression using a Probit technique (Greene, 2002) because we are only interested in determining whether or not students delayed, not the length of the delay. Independent variables include a student's gender, age, high school GPA, ACT mathematics and English scores, race, major, and major requirement of introductory microeconomics. The results of the regression are reported in column 2 of Table 3.

Results show that men are significantly more likely to delay taking developmental mathematics than women, despite the fact that there is no statistically significant difference between genders in terms of who places into developmental mathematics. Black and Hispanic students are less likely to delay taking their required mathematics course, though this is not significant. Other factors that make a student significantly less likely to delay the course include age and whether the student is a business major. A poor high school GPA is associated both with a greater likelihood of having to take developmental mathematics and a higher probability of delay in completing the requirement. A lower score on the ACT mathematics section increases a student's likelihood to delay developmental mathematics, indicating the student may have a serious mathematics aversion (see Table 3).

Table 3
Determinants of Delaying Taking Developmental Mathematics

Student Characteristics	Dependent Variable is "Delay Taking Developmental Mathematics" Versus "No Delay"
Male	0.32
	(2.29)**
Age	-0.10
	(-2.37)**
High School GPA	-0.66
	(-2.64)***
ACT English Score	0.01
	(0.37)
ACT Mathematics Score	-0.08
	(-3.59)***
Minority (Black or Hispanic)	-0.26
	(-1.18)
English is Native Language	-0.58
	(-1.46)
Business Major	-0.51
	(-3.24)***
Economics is Required for	0.01
The Student's Major	(0.03)
Constant	4.15
	(3.14)**
Pseudo R-squared, N observations	$R^2 = 0.11$, $N = 1462$

*Numbers in parenthesis are t-statistics. Significance is indicated as * = 10%, ** = 5%, and *** = 1%.

Costs of Delaying Developmental Mathematics

To determine whether delaying is harmful to developmental mathematics students' performance in other courses, we consider the following regressions. Our dependent variable—the percentage of questions answered correctly on all tests in the microeconomics course—is an approximately continuous numerical scale. The average percentage in the sample is 72.59% (SD = 13.50). An Ordinary Least Squares estimation approach is used.

Our explanatory demographic and family background variables include gender, minority, university class-level, hours spent working, and hours students report studying for all classes. We also include previous classroom exposure to economics, including if a student had taken economics in high school, had taken introductory macroeconomics, or was retaking introductory microeconomics. It is important to include these control variables to avoid omitted variable bias. Because we cannot directly observe the intelligence, ability, or motivation of students, we use proxy variables to attempt to capture these effects. We include students' GPAs, ACT mathematics and English scores, and mathematics courses taken. All variables passed an F-test of inclusion in the model and are consistent with other statistical studies of academic performance in economics (Ballard & Johnson, 2004; Durden & Ellis, 1995; Ely & Hittle, 1990; Hagedorn et al., 1999; Penny & White, 1998).

Consistent with other studies (Ballard & Johnson, 2004; Durden & Ellis, 1995; Ely & Hittle, 1990), we find GPA is positively and significantly related to student success in microeconomics. Men outscored women in the class, even controlling for mathematics background. Study results indicate that Black and Hispanic students are predicted to earn about 2.5 points fewer than their nonminority counterparts. Results make clear that students face a trade-off between work and study time. The more hours a student works in paid employment, the lower their score in microeconomics; conversely, the more hours a student reports studying, the higher their score.

Students with better mathematics skills do significantly better in introductory microeconomics, holding all other factors constant. Calculus and a higher ACT Mathematics score are strongly associated with higher grades in economics. Given the estimated coefficients, a student who took calculus, never was required to take developmental mathematics, and scored a 25 on the Mathematics ACT would score 8.93 percentage points higher in the course than a student who did not take calculus, who was required to take developmental mathematics, and who scored a 20 on the mathematics ACT. This is the equivalent of a full letter grade difference.

Our main finding is that students required to take developmental mathematics suffer from mathematics deficiencies that harm their ability to succeed in other, nonmathematics courses such as microeconomics.

Students required to take developmental mathematics who had completed it at the time of enrolling in microeconomics earned an average score that was 1.69 percentage points lower than students enrolling with adequate prerequisite skills (a statistically significant result). Students concurrently enrolled

Table 4
Student Characteristics and Performance in Microeconomics

Student Characteristics	Estimated Impact on Percentages of Points Earned in Microeconomics	*t*-statistics
Male	1.50	2.32**
Class[a]		
Sophomore	-6.91	-5.32***
Junior	-5.68	-3.94***
Senior	-6.79	-3.42***
Other	5.59	1.51
Minority (Black or Hispanic)	-2.62	-2.52**
Hours Work in Paid Job Per Week	-0.13	-3.95***
Hours Study Per Week (student reported)	0.12	3.26***
Took Economics in High School	-0.38	-0.60
Taken Micro Principles Before	2.84	1.72*
Taken Macro Principles Before	-0.68	-1.62*
GPA	2.27	9.08***
College of Business Major	-1.11	-1.83*
Course Required for Major	0.96	1.66*
Taken Calculus	2.61	3.60***
Required to take Developmental Mathematics		
Required and have taken developmental mathematics	-1.69[a]	-1.91*
Concurrently taking developmental math	-4.00	-1.73*
Required and have not taken developmental mathematics	-4.69	-2.82***
ACT Mathematics Score	0.75	6.83***
ACT English Score	0.33	3.36***
Took Course in 1999	1.39	2.22**
Constant	33.75	6.80***
R-squared, number of Observations	0.252, *N* = 1462	

Significance levels are indicated: *=10%, **=5%, and ***=1%
[a]The reference category is freshmen. The comparison category in this case is students who were not required to take remedial mathematics.

in developmental mathematics and microeconomics scored 4.00 percentage points lower in the course. Further, students required to take the developmental course who had not yet done so scored 4.69 percentage points less than their nondevelopmental counterparts (a highly significant result equivalent to half a letter grade, i.e., 2.5 vs. 3.0). Although placement into developmental mathematics appears to put students in a deficit position in courses with a quantitative element, students who took their required developmental mathematics course did better than the students who had not yet taken this required course (see Table 4).

Discussion and Recommendations

Several conclusions can be drawn from this analysis. Although an examination of the data suggests that students required to take developmental mathematics performed significantly worse than their nondevelopmental peers in an introductory microeconomics course, this study does indicate several recommendations. The most encouraging evidence we find is that although the mathematics skills of developmental students are not fully be on par with their nondevelopmental counterparts, having taken developmental mathematics appears to improve students' grasp of basic mathematical concepts compared to those who are required to take developmental mathematics and have not yet done so. Students who took their required developmental mathematics course prior to enrolling in introductory microeconomics earned two and a half percentage points more in their economics course than students required to take developmental mathematics but who had not done so. Further, the students who had completed the mathematics requirement were also much less likely to fail microeconomics. This result was highly significant. Thus, universities looking to improve student performance and retention should take a careful look at what the necessary prerequisites for courses should be.

The results of this study support the need for developmental mathematics, and also support the need for improving the effectiveness of developmental mathematics programs. Both the content and the structure of developmental mathematics courses should be examined. This study does not investigate different pedagogical approaches to the teaching of developmental mathematics, but it is suggestive as to why developmental mathematics is important for students outside the usual mathematics curriculum. The study also raises the stakes as to the importance of effective teaching methods for developmental mathematics and can point researchers to variables that might impact and improve developmental mathematics curriculum.

Hammerman and Goldberg (2003) believe the negative attitudes of students prevent them from successfully completing developmental mathematics courses at the college level. Perhaps one way to address these attitudes is to emphasize the importance of the developmental course mathematics skills in other disciplines. Since introductory microeconomics is required for all business majors, and since so many students are or intend to be business majors, emphasizing that developmental mathematics skills will help them earn better grades in their business courses could prove a motivating factor.

In addition, results support the implementation of policy requiring students to take developmental mathematics at the start of their university careers. Advantages of such a requirement accrue not only in more advanced mathematics courses, but this study has revealed that students also do better in a course that relies on basic mathematics concepts but is not highly quantitative. Students who took developmental mathematics prior to enrolling in introductory microeconomics scored significantly higher in the course than students who had put off their developmental mathematics course. This finding underscores the importance of an advisement program that leads students to good decisions by informing them of the consequences of their course selections. In addition, universities can target those students most likely to delay taking developmental mathematics by identifying certain student characteristics, similar to identifying at- risk students, and monitor their reactions to advising recommendations.

Another avenue of future research would be to see if this result holds in other courses with a quantitative element such as introductory accounting, finance, computer science, statistics, physics, or chemistry. Similar findings in these disciplines may support the need for students who fail their university math-

ematics placement exam to be required to take developmental mathematics immediately in—or perhaps even prior to—their first semester at college.

Conclusion

This study examines the cross-disciplinary effects of developmental mathematics, particularly examining the relationship between mathematics skills and student performance in introductory microeconomics. Although introductory microeconomics requires only the most basic use of mathematical concepts, students with higher mathematics ACT scores and higher university mathematics placement scores have earned more points in the course. Students who completed their developmental mathematics requirement prior to enrolling in introductory microeconomics fared much better than their counterparts who had not yet met their mathematics requirement. This suggests both the importance of appropriate course prerequisites as well as university policies designed to help students complete their required developmental courses early in their college careers.

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