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Predicting Successful Mathematics Remediation Among Latina/o Students

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Abstract

This study examines Latina/o students' remedial math needs and outcomes. Data were drawn from a national sample of Latina/o students. Hierarchical generalized linear modeling techniques were used to predict three successful remediation outcomes. Results highlight the importance of providing financial aid and academic support to Latina/o students, especially those who have the highest remediation needs. Findings also have direct implications for policy and practice by providing a means for targeting students who are at greatest risk.

Resumen

Este estudio examina necesidades y resultados remediales en matemáticas para estudiantes latina/os. Información fue obtenida de una muestra nacional de estudiantes latina/os. Técnicas de modelo linear de jerarquía generalizada fueron usadas para predecir tres resultados de éxito remedial. Resultados subrayan la importancia de proveer ayuda financiera y apoyo académico a estudiantes latina/os, especialmente a aquellos que tienen la más alta necesidad remedial.

Keywords

Latina/o students, developmental education, remediation, mathematics, STEM

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Increasing degree completion rates for Latina/o students is critical for the United States to meet its future workforce and societal needs (Santiago, 2011). Latina/os are projected to make up one fourth of the total population by 2050 (Llagas & Snyder, 2003), and yet this group continues to lag behind others in terms of degree completion (Fry & Lopez, 2012; U.S. Census Bureau, 2012) in what has been referred to as "the Latina/o educational crisis" (Gándara & Contreras, 2009). Although Latina/os comprise more than 16% of the U.S. population (Ennis, Ríos-Vargas, & Albert, 2011), this group earned only 12% of the total number of associate's degrees, 8% of the total number of bachelor's degrees, 6% of the total number of master's degrees, and 4% of the total number of doctoral degrees conferred during the 2008-2009 academic year (U.S. Department of Education, National Center for Education Statistics [NCES], 2011). There is a particular need to increase the number of Latina/os earning undergraduate degrees in science, technology, engineering, and mathematics (STEM) fields (Chen & Weko, 2009). Unfortunately, substantial gaps exist with regard to how institutions can effectively promote equity in degree completion, both in and outside of STEM fields, among Latina/o students (Crisp & Nora, 2012).

Overlapping economic, structural, and cultural conditions prior to and during college, including but not limited to poverty, racism, and cultural dissonance in school norms, serve as barriers to degree completion for Latina/o students (Aud, Fox, & KewalRamani, 2010; Boykin, Tyler, & Miller, 2005; Caldwell & Siwatu, 2003; Foster, Lewis, & Onafowora, 2003; Ladson-Billings, 1995). Latina/o students disproportionally attend underresourced public schools (Gándara & Contreras, 2009) that may negatively affect instruction quality (Vartanian & Gleason, 1999) and equitable access to college-level preparatory coursework, including advanced mathematics courses (Adelman, 2006). There is also evidence to suggest that Latina/o students are more likely to be tracked into vocational or lower-level coursework when compared with White students (Meier & Stewart, 1991; National Assessment of Educational Progress, 2005). As a result, Latina/o students often begin postsecondary education with lower levels of college readiness. At the same time, Latina/o students are more likely than their White student counterparts to be first-generation college students (Saenz, Hurtado, Barrera, Wolf, & Yeung, 2007) and/or to postpone enrolling in college after high school (Santiago & Stettner, 2013), which are two factors that may negatively affect student success.

Given these conditions, it may not be surprising that Latina/o students are overrepresented in developmental courses in college (Bettinger & Long, 2005; Sparks & Malkus, 2013). Developmental education, also referred to as remedial or basic skills education (Bailey, Jeong, & Cho, 2010; Dotzler, 2003; Ignash, 1997), includes courses and services designed to provide underprepared students with the skills they need to successfully pass college-level coursework (Bettinger & Long, 2005; Boylan & Bonham, 2007; Boylan & Saxon, 2000). Many view developmental education as an opportunity that opens doors to economic and educational advancement for traditionally underrepresented groups (Bahr, 2010), including Latina/os (e.g., Grimes & David, 1999; Penny & White, 1998). Unfortunately, students who do not successfully pass through remedial course sequences have been shown to be less likely to attain a degree

or certificate or to transfer to a 4-year institution (e.g., Bahr, 2008a, 2008b; Bettinger & Long, 2004).

An understanding of the role of remediation in shaping Latina/o students' postsecondary choices and outcomes is imperative (Howell, 2011). Because students enroll in remedial math courses more than any other subject area (Bahr, 2007), there is a particular need to understand the obstacles faced by students who require remediation in mathematics (Bahr, 2008b). Bahr (2013) notes that a majority of community college students require some type of remedial assistance with mathematics, indicating that many students arrive at college underprepared for college-level math, a "gatekeeper" course that may keep students from progressing through their course sequence into more advanced courses (Roksa, Jenkins, Jaggars, Zeidenberg, & Cho, 2009). There is evidence that remediation in math may be a substantial barrier to college-level courses and transfer for Latina/o community college students in particular. For instance, a policy brief by Solórzano, Acevedo-Gil, and Santos (2013) reported that, out of 100 Latina/o community college students in California who placed into developmental math, only 14 successfully completed a college-level transferable course within 3 academic years. Regrettably, findings reveal that the majority of students requiring math remediation do not successfully attain college-level math skills (Bahr, 2008b) and that Latina/o students are even less likely than White and Asian American students to remediate successfully (Bahr, 2010). Considering that Latina/o students are overrepresented in community colleges (Hagedorn, Chi, Cepeda, & McLain, 2007) and developmental courses and activities (Nora & Crisp, 2012), more research is needed to understand the factors that predict Latina/o student success in these crucial courses that contribute to their attainment of a postsecondary degree or certificate.

Very little is known regarding the characteristics and outcomes of Latina/o students who remediate in mathematics. Moreover, no study to date has modeled the characteristics associated with successful math remediation among Latina/o college students. As such, the purpose of the present study was to examine Latina/o students' developmental math needs and outcomes using national data from the Beginning Postsecondary Students Longitudinal Study (BPS: 04/09) and recent BPS Postsecondary Education Transcript Study (PETS). Our analysis addressed the following research questions:

Research Question 1: What characteristics, behaviors, and experiences describe Latina/o students who enroll in developmental mathematics courses?
Research Question 2: What factors contribute to (a) passing development math, (b) enrolling in college-level math, and (c) passing college-level math among Latina/o students?

Literature Review

The following section provides context and empirical grounding to the conceptual framework and analyses by synthesizing work to date focused on developmental students' characteristics and outcomes, giving emphasis to research focused specifically on developmental math and/or Latina/o students. Descriptive findings by Nora and

Crisp (2012) suggest there may be substantial differences between the characteristics and outcomes of Latina/o students who do and do not enroll in developmental coursework. In particular, data revealed that Latina/o students who enrolled in developmental courses were more likely to be female, to be Mexican American, to have a lower high school grade point average (GPA), to have taken less rigorous math courses in high school, and to receive lower levels of financial aid when compared with their nonremedial counterparts. Results also indicated that the majority of Latina/o students enrolled in developmental education were enrolled in one or more mathematics courses. It is notable that among students enrolled in developmental courses, Latina/os who began college at a 4-year institution were shown to be more likely to earn a college degree or persist to the end of the second or third year of college when compared with students who began their postsecondary education at a community college.

Although not specific to Latina/o students, there is a growing body of work documenting the characteristics of students who remediate in mathematics. In sum, findings indicate that developmental math students are systematically different from students who do not require remediation in terms of gender, ethnicity, age first-generation status, academic preparation, high school GPA, and delayed college entry (Calcagno, Crosta, Bailey, & Jenkins, 2007; Crisp & Delgado, 2014; Hagedorn, Siadat, Fogel, Nora, & Pascarella, 1999). Interestingly, recent findings by Benken, Ramirez, Li, and Wetendorf (2015) suggest that students who enroll in developmental math may not be substantially different from students who enroll in college-level math in terms of the number of mathematics courses taken in high school. Findings revealed that the majority (66%) of developmental math students enrolled at a university in the California State system had taken math courses in all 4 years of high school. At the same time, Bahr's (2010) analysis of students in California found that Latina/o students were more likely than White students to enter college at the lowest level of remedial math skill. Bahr concluded that the degree of math deficiency entering college likely contributed to the overrepresentation of Latina/o students in remediation. Yet, little is known regarding the characteristics, behaviors, and experiences of Latina/o students who enroll in developmental math courses. As such, additional work is needed to describe Latina/o students who enroll in postsecondary education unprepared to take college-level mathematics coursework.

A critical literature review by Melguizo, Bos, and Prather (2011) highlights the absence of research on the impact of enrolling in developmental mathematics that properly controls for student characteristics and precollege experiences. Exceptions include recent work by Moss, Yeaton, and Lloyd (2014) who used a rigorous embedded randomized experiment within a regression discontinuity design to examine developmental math outcomes at a large Midwestern university, finding participation in developmental math to be effective. Similarly, Bettinger and Long (2005) found that, among a sample of community college students in Ohio, those who enrolled in remedial math courses were more likely to transfer to a 4-year institution than those with comparable test scores and precollege academic preparation who did not enroll in remedial math. Fong, Melguizo, and Prather (2015) found that students who persisted in developmental math were "catching up" and were even more successful than students who

were more academically prepared for college-level math. At the same time, other studies have found developmental math to have similar or even negative outcomes when compared with students who do not enroll in developmental mathematics courses (e.g., Bahr, 2008b, 2010). For instance, findings by Crisp and Delgado (2014) indicated that enrolling in developmental math courses (after reducing selection bias and controlling for student-level and institutional variables) served to decrease community college students' odds of transferring to a 4-year institution within 6 academic years. Moreover, Bahr (2008b) found that the majority of students requiring math remediation do not successfully attain college-level math skills.

In addition to assessing the overall effectiveness of developmental math, researchers have been increasingly engaging in work to identify student and institutional characteristics associated with students' success in developmental math courses. These findings have consistently shown several student characteristics and experiences to be related to or predictive of students' success in developmental math including gender, age, high school experiences, socioeconomic status, and enrollment intensity and patterns during college (Bahr, 2010; Fong et al., 2015; Roksa et al., 2009). In particular, research by Roksa et al. (2009) found that female community college students in Virginia who were 25 years or older were more likely to successfully complete developmental and college-level gatekeeper math courses. Additionally, Bahr's (2010) work suggests that English competency, several proxies of socioeconomic status, and high school math courses taken served to predict successful remediation among community college students in California. Moreover, Fong et al. (2015) recently found that attending college full-time and receiving financial aid were positively related to the odds of community college students' progressing through the entire developmental math course sequence. Furthermore, work by Zientek, Ozel, Fong, and Griffin (2013) indicated that community college students' grades in developmental mathematics were positively related to class attendance and repeating a mathematics course. The researchers also found students' beliefs and perceptions to increase success such as self-regulated learning and meeting others' expectations. Not surprisingly, a negative relationship between the level of math remediation required and the probability of passing gatekeeper math courses was identified by Roksa et al. (2009), who found that less than 20% of students from all ethnic/racial groups who enrolled in the lowest level of developmental math coursework subsequently enrolled in a college-level math course. A limited amount of work has also been done to identify institutional factors associated with developmental math outcomes. For example, Fong et al. (2015) found that the percentage of students on campus who were Latina/o as well as the percentage of high school graduates on campus increased students' odds of attempting elementary algebra courses. In addition, findings revealed the percentage of certificates awarded by the institution was related to passing intermediate algebra.

Despite the prevalence of Latina/o students in developmental courses and inequities in outcomes, there is little evidence to understand the role of remediation in promoting or hindering academic success outcomes specifically among Latina/o students (Nora & Crisp, 2012). The limited amount of existing work suggests that, when compared with White students, Latina/o students have higher odds of attempting developmental math

but are less likely to pass each level (Fong et al., 2015). Research by Crisp and Nora (2010) indicated that, among Latina/o community college students, the odds of persisting in college and/or earning a degree in the second year of college were positively related to enrolling in remedial courses. No relationship was found, however, between remediation and outcomes in the students' third year of college. Findings also suggest that Latina/o developmental students' persistence and/or degree outcomes were positively related to parental education, not working more than 20 hr per week off campus, receiving enough financial aid to pay for college, and enrolling full-time. Furthermore, recent work by Acevedo-Gil, Santos, Alonso, and Solorzano (2015) found that remedial students experienced both validation and invalidation in their interactions with institutional agents in developmental settings, further complicating the role of developmental education in these students' academic experiences. It is notable that no study to date has modeled the characteristics and experiences associated with successful math remediation specifically among Latina/o students. Our research seeks to address this gap by examining the characteristics and experiences that serve to predict successful outcomes for this important and yet largely understudied group of students.

Method

Sample

Our analytic sample included the 640[1] Latina/o students attending 290 institutions in the BPS (04/09) data set who (a) enrolled in one or more remedial math courses, (b) had complete institutional data, and (b) were less than 24 years of age. The decision to limit the sample to traditional age students was based on limitations of the BPS data, which do not capture complete data for high school related data elements for older students. However, note that traditional age students represent 90% of the Latina/o students in the data set. The subsample of traditional aged Latina/os was further shown to be representative of the national sample.

Variables/Conceptual Model

A survey item in the PETS for BPS was used to flag students who enrolled in remedial math coursework within 6 academic years. Developmental courses were identified using the 2010 College Course Map, which provides a taxonomy system for coding classes. Consistent with the above-mentioned research on developmental education, three measures of "successful remediation" were examined, including (a) earning a passing grade in all developmental math courses taken, (b) enrolling in a college-level math course within 6 academic years, and (c) earning a passing grade in a college-level math course within 6 academic years. A broad range of courses was coded by NCES as college level, including algebra, geometry, applied mathematics, statistics, Algebra for teachers, and business math (Bryan & Simone, 2012).

The conceptual model guiding the hierarchical generalized linear modeling (HGLM) analyses was developed from the empirical research discussed in our review

that has sought to identify relationships between student and institutional characteristics and outcomes for developmental math and/or Latina/o students. As suggested by Melguizo et al. (2011), our model accounts for various characteristics and precollege experiences. Moreover, our model was informed by Crisp and Nora's (2010) framework that seeks to identify variables contributing to Latina/o community college students' persistence and transfer decisions (including enrollment in developmental coursework). As shown in the appendix, the model posits that, among Latina/o students, successful remediation is influenced by a combination of *sociodemographic and precollege variables, degree expectations, academic experiences and pull factors*, and *institutional-level characteristics*. In particular, students' gender, age, Latina/o ethnic subgroup, first-generation status, high school GPA, highest math course taken in high school, and whether or not college-level credit was earned prior to enrolling in college were hypothesized to be related to Latina/o students' odds of successfully remediating in math. We specifically expected that being female, older, a continuing generation student, having a higher GPA, enrolling in advanced math courses during high school and earning college credit prior to college would be positively related to math remedial outcomes among Latina/o students (Bahr, 2010; Crisp & Nora, 2010; Fong et al., 2015; Roksa et al., 2009). Drawing from the broader literature on Latina/o students (e.g., Arbona & Nora, 2007; Cerna, Pérez, & Saenz, 2009; Suarez, 2003), we also hypothesized that students' degree expectations during the first year of college would be significantly positively related to math remediation outcomes.

Two college experiences, often termed *environmental pull factors* (Nora, 2003) were assumed to increase the odds that students will successfully remediate, including the amount of financial aid (i.e., loans, grants) received during the first year of college and enrolling in college full-time (Crisp & Nora, 2010; Fong et al., 2015). Conversely, several experiences and pull factors were expected to decrease students' odds of success, namely, enrolling in a higher number of developmental math courses, working off campus, stopping out of college, and enrolling in one or more developmental English courses (Crisp & Nora, 2010; Roksa et al., 2009). Drawing from recent findings by Acevedo-Gil et al. (2015) as well as research more generally focused on Latina/o students (e.g., Arellano & Padilla, 1996; Bordes, Sand, Arredondo, Robinson-Kurpius, & Rayle, 2006; Castellanos & Jones, 2003; Crisp, 2011), we hypothesized that support from faculty and/or peers would serve to positively influence success outcomes. Although it would have been desirable to include separate measures for faculty and peers, these survey items were very highly correlated. As such, our model includes a reliable composite of academic support received from faculty and peers.

Research by Bahr (2010) and Fong et al. (2015) suggests that institutional-level characteristics, including the representation of Latino/o students on campus, serve to contribute to students' individual success in remedial courses. In addition, the broader line of research on Latina/o students (e.g., Alfonso, 2006; Cerna et al., 2009; Crisp & Nora, 2010; Melguizo, 2009) led us to expect that students' remedial success would be influenced by institutional-level variables. Our conceptual model thus posited that institutional characteristics, including level, type (public or private), enrollment size, the percent of Latina/o students attending the institution, and the percentage of the

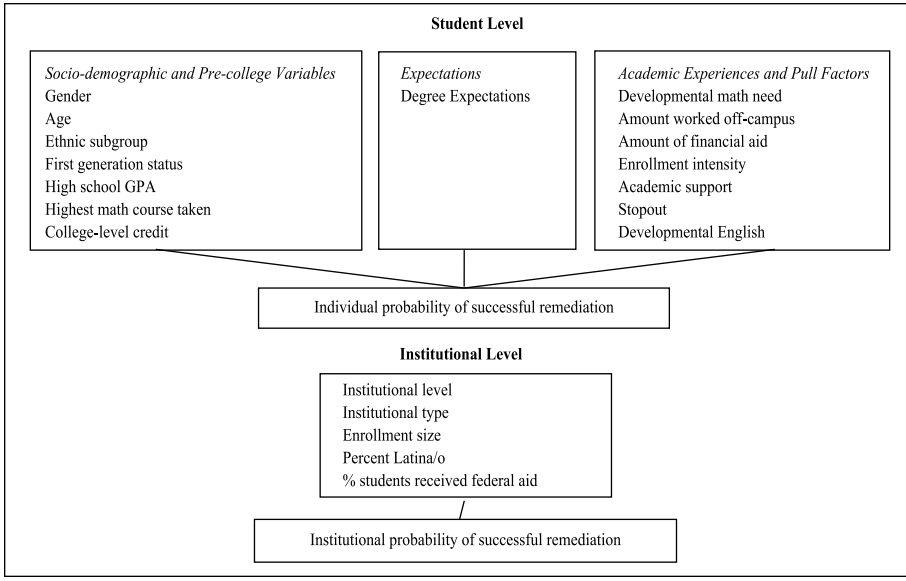

Figure 1. Conceptual model.
Note. GPA = grade point average.

student body that received federal aid, would serve to influence Latina/o students' remedial outcomes (Figure 1).

Analysis

Percentages were used to describe the characteristics and experiences of Latina/o students who enroll in remedial mathematics courses. Missing data (2.14%) were handled using multiple imputations (MI; Enders, 2008). As a test of multicollinearity within the model, the variance inflation factor (VIF) was examined for each of the predictor variables. All variables were found to have a VIF equal to or less than 2.5 and were therefore retained for subsequent analysis. HGLM techniques were then utilized to account for the impact of student and institutional characteristics on successful remediation. Given the binary outcomes (e.g., passing vs. not passing developmental math) and the nested nature of students within postsecondary institutions in the BPS data, HGLM was the appropriate analytic technique to use (Raudenbush & Bryk, 2002). We ran an unconditional model to provide a measure of estimated remedial success rates for the sample of 290 institutions. According to Raudenbush and Bryk (2002), the dichotomous nature of the outcomes makes calculating the intraclass correlation (ICC) noninstructive. In turn, we evaluated box plots estimated from empirical Bayes residuals. We then added student-level predictors to estimate the variables that were significantly related to our three measures of successful remediation. All equations were fixed

to constrain the effect of the within-institutional predictors to be the same for all institutions and variables were grand mean centered to ease interpretation of parameter estimates and control for differences in student-level characteristics and experiences between institutions (Raudenbush & Bryk, 2002). The Level 1 structural model took the form:

$$\begin{aligned}\log\left[\varphi_{1j}/1-\varphi_{1j}\right] &= \beta_{0j}+\beta_{1j}\left(\mathrm{MALE}\right)_{ij}+\beta_{2j}\left(\mathrm{AGE}\right)_{ij}+\beta_{3j}\left(\mathrm{CUBAN}\right)_{ij}\\ &+\beta_{4j}\left(\mathrm{PUERIC}\right)_{ij}+\beta_{5j}\left(\mathrm{MIXOTH}\right)_{ij}+\beta_{6j}\left(\mathrm{CONTCOL}\right)_{ij}\\ &+\beta_{7j}\left(\mathrm{GPA1}\right)_{ij}+\beta_{8j}\left(\mathrm{GPA2}\right)_{ij}+\beta_{9j}\left(\mathrm{GPA3}\right)_{ij}+\beta_{10j}\left(\mathrm{GPA4}\right)_{ij},\\ &+\beta_{11j}\left(\mathrm{TRIG}\right)_{ij+}+\beta_{12j}\left(\mathrm{PRECAL}\right)_{ij},+\beta_{13j}\left(\mathrm{CALCULUS}\right)_{ij}\\ &+\beta_{14j}\left(\mathrm{COLCRED}\right)_{ij}+\beta_{15j}\left(\mathrm{BACH}\right)_{ij}+\beta_{16j}\left(\mathrm{MASTER}\right)_{ij}\\ &+\beta_{17j}\left(\mathrm{DOCTORAL}\right)_{ij}+\beta_{18j}\left(\mathrm{AMTDEMA}\right)_{ij}\\ &+\beta_{19j}\left(\mathrm{WKPART}\right)_{ij}+\beta_{20j}\left(\mathrm{NOWORK}\right)_{ij}+\beta_{21j}\left(\mathrm{FINAID1}\right)_{ij}\\ &+\beta_{22j}\left(\mathrm{FINAID2}\right)_{ij}+\beta_{23j}\left(\mathrm{FINAID3}\right)_{ij}+\beta_{24j}\left(\mathrm{FINAID4}\right)_{ij},\\ &+\beta_{25j}\left(\mathrm{FULLTIME}\right)_{ij},+\beta_{26j}\left(\mathrm{ACASUP}\right)_{ij},+\beta_{27j}\left(\mathrm{NOSTOP}\right)_{ij}\\ &+\beta_{28j}\left(\mathrm{NOREMENG}\right)_{ij}.\end{aligned} \tag{1}$$

Level 2 predictors were then added to measure hypothesized contextual influences on the three measures of successful remediation. Following practice by Porchea, Allen, Robbins, and Phelps (2010), only institution-specific random intercepts were specified. The Level 2 structural model was estimated as follows:

$$\begin{aligned}\beta_{0j} &= \gamma_{00}+\gamma_{01}\left(\mathrm{4YEAR}\right)_j+\gamma_{02}\left(\mathrm{PUBLIC}\right)_j+\gamma_{03}\left(\mathrm{SIZE}\right)_j+\gamma_{04}\left(\mathrm{PERLATINO}\right)_j\\ &+\gamma_{05}\left(\mathrm{INSTAID}\right)_j+u_{0j},\\ \beta_{1j} &= \gamma_{10},\\ \beta_{17j} &= \gamma_{280},\end{aligned} \tag{2}$$

The sampling model was Bernoulli:

$$\mathrm{Prob}\left(\mathrm{Yjj}=1/\beta\mathrm{ij}\right)=\varphi\mathrm{ij}. \tag{3}$$

Our models were estimated using a high-order Laplace approximation of maximum likelihood (ML) because this approach has been shown to produce accurate approximations to ML for all parameters (Raudenbush, Yang, & Yosef, 2000). We compared unit-specific, model-based, and robust standard errors to identify possible misspecifi-

cation of the distribution of random effects (Raudenbush & Bryk, 2002). Logit coefficients were then interpreted using odds ratios (Peng, So, Stage, & St. John, 2002).

Limitations

Several data limitations should be taken into consideration when interpreting the results. First, the BPS (04/09) data do not account for variation in the levels of remediation, as research suggests that students may enroll in more than three levels of remediation (Bailey et al., 2010). The database also does not include information about state or institutional developmental policy, making it unclear whether students were required or chose to enroll in the developmental math courses taken. Third, little information was available regarding the classroom environment, including instructional quality, pedagogical strategies, or whether courses were connected with a learning community or other form of student support programming such as supplemental instruction. Finally, although the present study properly controls for the institutional context, it was not possible given data limitations to conduct a three-level HGLM to account for students nested in developmental math courses.

Results

Description of Latina/o Developmental Math Students

As shown in Table 1, among the national sample of 640 Latina/o students ages 17 to 23 who enrolled in a developmental math course in the 2003-2004 academic year, 61% successfully passed developmental math, 54% successfully enrolled in a college-level mathematics course, and 46% successfully earned college-level math credit within 6 academic years. Only 37% of students were male and nearly half identified as being of Mexican American or Chicano decent (45%). One fifth (20%) were Puerto Rican, 3% identified as Cuban, and the remaining 32% of the sample identified as being of mixed or "Other" Latino/a origin. The overwhelming majority of Latina/o students who enrolled in developmental math did not have a parent who had earned a college degree (77%).

Sixty-two percent of the sample earned a high school GPA of 3.0 (B) or higher. Nearly half (43%) of students completed Algebra 2 as the highest math course in high school, 39% took a course that covered Algebra 2 and trigonometry, and only 19% had completed a pre-calculus or calculus course prior to college. Roughly one fourth of students (22%) earned college credit during high school. During the first year of college, more than half (57%) of the sample indicated that they expected to earn a bachelor's *and* graduate degree.

Twenty-six percent of the national sample received no financial aid (including grants, loans, and other forms of support) and only 19% reported receiving more than US$10,000 of aid from any source during the first year of college. More than one third of the Latina/o students (35%) who enrolled in a developmental math course worked full-time and another nearly half (45%) reported working part-time during the first year in college. Slightly less than half (49%) of students were able to enroll in college

Table 1. Descriptive Statistics.

	%	*M*	*SD*	Minimum	Maximum
Sociodemographic and precollege variables					
Male	37.3				
Age		18.8	1.3	17.0	23.0
Ethnic subgroup					
Mexican American or Chicano	45.2				
Cuban	2.8				
Puerto Rican	19.8				
Other or Mixed Latino origin	32.2				
Continuing generation status	23.3				
High school grade point average					
Less than 2.0	2.8				
2.0 to 2.4	15.8				
2.5 to 2.9	19.7				
3.0 to 3.4	49.2				
3.5 to 4.0	12.5				
Highest math course taken					
Algebra II or lower	42.5				
Trigonometry and Algebra	38.9				
Pre-calculus	13.8				
Calculus	4.8				
College-level credit in high school	22.3				
Highest degree expected					
Less than a bachelor's degree	10.6				
Bachelor's degree	32.0				
Master's degree	37.8				
Doctoral or professional degree	19.5				
Academic experiences and pull factors					
Developmental math need					
Amount worked off campus					
Worked full-time	35.3				
Worked part-time	45.3				
Did not work	19.4				
Amount of financial aid support					
No aid received	25.9				
Less than US$2,500	15.2				
Between US$2,500 and US$4,999	21.3				
Between US$5,000 and US$9,999	19.1				
More than US$10,000	18.6				
Enrolled full-time	48.8				
Academic support		0.6	0.4	0	2.0
Did not stopout	49.4				
Institutional-level variables					
4-year institution	31.9				
Institutional control					
Public	68.6				
Private nonprofit	18.8				
Private for-profit	12.7				
Enrollment size		10,451.8	9,473.5	75	47,952.0
Percentage Latino/a students		35.4	31.2		
Percentage students received aid		46.1	24.0		
Successful remediation outcomes					
Passed developmental math	61.4				
Enrolled in college-level math	54.1				
Passed college-level math	46.3				

Source. BPS: 04/09, PETS, and IPEDS survey data.
Note. Sample includes 640 Latino/a students attending 290 institutions. BPS = Beginning Postsecondary Students Longitudinal Study; PETS = Postsecondary Education Transcript Study; IPEDS = Integrated Postsecondary Education Data System.

exclusively full-time and 51% stopped out, defined as a break in enrollment for five or more consecutive months of college, at some point during their undergraduate career. Forty-four percent of students enrolled in only one developmental math course, while 23% enrolled in two courses and the remaining third (33%) enrolled in three courses. Only 8% of students who enrolled in remedial math also enrolled in a developmental English course.

Two thirds (68%) of the Latina/o students enrolled in developmental math did not begin college at a 4-year institution. The large majority of the sample attended a public institution (69%) while 19% attended a private nonprofit institution and 12% attended a private institution classified as a for-profit. The average size of the first institution that the student attended was 10,451 students. Although some Latina/o students attended an institution where only 1% of the student body identified as Latina/o and some attended institutions where 100% of students were Latina/o, the average was 35%.

Predictors of Successful Remediation

Results of the unconditional models predicting (a) passing development math, (b) enrolling in college-level math, and (c) passing college-level math indicated that the odds of successful remediation varied significantly across institutions ($p < .05$). Moreover, an inspection of the plots suggested variation between institutions in the estimated chance of successful remediation, indicating that the use of within- and between-institution models was appropriate. As such, we proceeded with the HGLM analysis (complete findings shown in Table 2).

The first HGLM model predicting Latina/o students' success of passing all developmental courses taken identified several student- and institutional-level variables associated with the odds of success. To begin with, students' odds of passing developmental math was shown to be positively related to receiving between US$5,000 and US$9,999 in financial aid ($p < .01$, odds ratio = 2.75) or more than US$10,000 in aid ($p < .01$, odds ratio = 3.49). The percentage of Latina/o students attending the institution was also shown to increase the odds of passing developmental math ($p < .05$, odds ratio = 1.012). Conversely, passing developmental math was found to be negatively associated with being of mixed or "other" Latina/o origin ($p < .05$), the number of developmental math courses taken ($p < .001$), and two institutional-level variables (i.e., attending a 4-year institution [$p < .01$] and the percentage students of receiving financial aid [$p < .05$]).

The second and third regression models seeking to predict taking and passing college-level math within 6 academic years identified very few variables significantly related to Latina/o students' odds of remedial success in math. Specifically, the amount of academic support received ($p < .05$, odds ratio = 1.82) and enrolling at a public institution ($p < .05$, odds ratio = 2.17) were found to significantly increase students' odds of enrolling in college-level math courses after completing developmental math. Similar to passing developmental math, Latina/o students' odds of taking a college-level math course was shown to be negatively associated with the amount of developmental courses taken ($p < .01$). The amount of developmental math

Table 2. Predictors of Successful Remediation Among Latina/o Students.

	Passed developmental math		Enrolled in college mathematics		Passed college mathematics	
	Coefficient (*SE*)	OR	Coefficient (*SE*)	OR	Coefficient (*SE*)	OR
Male	−.263 (.242)	—	.089 (.229)	—	−.089 (.237)	—
Age	−.029 (.091)	—	.013 (.086)	—	−.0223 (.083)	—
Ethnic subgroup (*Mexican American*)						
Cuban	1.54 (.861)	—	.034 (.648)	—	.445 (.681)	—
Puerto Rican	.000 (.343)	—	.303 (.341)	—	.151 (.342)	—
Other or Mixed Latino origin	−.587 (.275)*	.556	.071 (.242)	—	−.169 (.266)	—
Continuing generation status	−.034 (.274)	—	.061 (.252)	—	.069 (.257)	—
High school GPA (*less than 2.0*)						
2.0 to 2.4	−.386 (.558)	—	−.192 (.740)	—	−.336 (.691)	—
2.5 to 2.9	.376 (.655)	—	−.277 (.731)	—	−.332 (.701)	—
3.0 to 3.4	.058 (.640)	—	.195 (.710)	—	.183 (.661)	—
3.5 to 4.0	.883 (.714)	—	.443 (.739)	—	.696 (.709)	—
Highest math course (*Algebra II or lower*)						
Trigonometry and Algebra	−.133 (.254)	—	−.061 (.251)	—	−.215 (.239)	—
Pre-calculus	.356 (.402)	—	.072 (.364)	—	−.067 (.364)	—
Calculus	−.392 (.543)	—	.252 (.605)	—	.338 (.594)	—
College-level credit in high school	−.020 (.276)	—	.009 (.260)	—	.080 (.267)	—
Highest degree (*less than bachelor's*)						
Bachelor's degree	.255 (.371)	—	.119 (.415)	—	.263 (.401)	—
Master's degree	.570 (.380)	—	.286 (.402)	—	.517 (.398)	—
Doctoral or professional degree	.102 (.412)	—	.120 (.472)	—	.551 (.450)	—
Developmental math need	−.847 (.131)***	.428	−.304 (.135)*	.737	−.285 (.131)*	.751
Amount worked off campus (*full-time*)						
Worked part-time	−.027 (.255)	—	−.180 (.266)	—	−.150 (.252)	—
Did not work	−.182 (.327)	—	−.689 (.351)	—	−.629 (.316)*	.532
Amount of financial aid support (*no aid*)						
Less than US$2,500	−.219 (.385)	—	−.594 (.375)	—	−.426 (.378)	—
Between US$2,500 and US$4,999	−.002 (.346)	—	.057 (.376)	—	.104 (.374)	—
Between US$5,000 and US$9,999	1.012 (.386)**	2.751	−.112 (.385)	—	.091 (.379)	—
More than US$10,000	1.251 (.431)**	3.494	.445 (.453)	—	.880 (.433)	—
Enrolled full-time	.095 (.227)	—	.300 (.235)	—	.218 (.243)	—
Amount of academic support	.103 (.254)	—	.596 (.284)*	1.816	.415 (.278)	—
Did not stopout	.451 (.237)	—	.232 (.229)	—	.271 (239)	—
Did not take developmental English	−.073 (.459)	—	−.115 (.427)	—	−.055 (.416)	—
Institutional-level variables						
4-year institution	−.794 (.228)**	.452	.173 (.300)	—	−.242 (.292)	—
Public institution	−.668 (.367)	—	.773 (.378)*	2.169	.548 (.374)	—
Enrollment size	.000 (.000)	—	.000 (.000)	—	.000 (.000)	—
Percentage Latino/a students	.012 (.005)*	1.01	.000 (.005)	—	.001 (.005)	—
Percentage students received aid	−.019 (.008)*	.980	−.003 (.008)	—	−.005 (.008)	—

Source. BPS: 04/09, PETS and IPEDS survey data.

Note. Sample includes 640 Latina/o students attending 290 institutions. BPS = Beginning Postsecondary Students Longitudinal Study; PETS = Postsecondary Education Transcript Study; IPEDS = Integrated Postsecondary Education Data System.

* $p < .05$. ** $p < .01$. *** $p < .001$.

courses taken ($p < .05$) and not working ($p < .05$) were the only two variables found to be related to students' odds of passing a college-level math course.

Discussion

The need to better understand what factors predict success in remedial math is crucial considering how remediation may negatively affect students' persistence in college (Bailey et al., 2010), especially considering that more than half of Latina/o students who enroll in community colleges require remediation (Complete College America, 2012). As this is the first study to model the characteristics associated with successful math remediation among Latina/o college students, present findings contribute to research in several ways. On the whole, results provide a better understanding of the role of various characteristics and experiences that promote success among Latina/o students who enter postsecondary education with academic deficiencies, highlighting the importance of providing specific types of support to this growing population of students. A wealth of research exists to provide evidence of the importance of providing various types of mentoring support and validating Latina/o college students (e.g., Arellano & Padilla, 1996; Bordes et al., 2006; Castellanos & Jones, 2003; Crisp, 2011; Rendon, 1994; Swail, Redd, & Perna, 2003). However, the present study is the first to identify faculty and peer support as a positive predictor of remedial success for Latina/o students (in or outside of mathematics).

Our study is also the first to identify institutional characteristics associated with successful math remediation among Latina/o students. Prior work by Hagedorn et al. (2007) would suggest that a "critical mass" of students is positively related to Latina/os student success outcomes. Furthermore, recent work by Cuellar (2014) found that, although Latina/o students enroll at Hispanic Serving Institutions (HSIs) with lower self-perceptions of their academic abilities when compared with their Latina/o peers at non-HSIs, this difference is leveled after 4 years in college. Current results, finding that the percentage of Latina/o students on campus is positively associated with students successfully passing developmental math courses, therefore add empirical support to the value of Latina/o students attending HSIs and/or institutions with a critical mass of Latina/os.

The present study further contributes to current knowledge regarding the behaviors and experiences of Latina/o students in developmental math courses. For instance, it is important to know that, among the national sample of Latina/o students, although 61% of students successfully passed developmental math, only 54% of the sample subsequently enrolled in a college-level mathematics course. Another seemingly important descriptive finding was that more than half (56%) of the national sample of Latina/o students enrolled in more than one developmental math course. This finding is particularly significant given that the amount of remediation was related to outcomes across all three HGLM models.

Implications for Research

On the whole, findings appear to be consistent with research specific to developmental education and/or Latina/o students. For instance, it comes as no surprise that

receiving more financial aid was shown to increase students' odds of successfully completing developmental math courses (Gross, Torres, & Zerquera, 2013; Santiago & Cunningham, 2005). However, a few of the findings are less clear and will require additional research to understand. For example, it is unclear why passing developmental math was found to be negatively associated with being of mixed or "other" Latina/o origin. Unfortunately, very little research exists to understand the experiences of mixed heritage students (Murakami-Ramalho, Nuñez, & Cuero, 2010). Another seemingly contradictory finding was that not working was found to decrease Latina/o students' odds of passing college-level math. It is possible that these students were advised to take too many hours (Bahr, 2008b) and/or were unemployed/underemployed and taking study time to pursue employment. Furthermore, it is unclear why attending a 4-year and/or a private institution was found to be negatively associated with passing developmental math, particularly when findings indicate that completion rates are higher at 4-year institutions and/or private institutions when compared with community colleges (Kena et al., 2015). Perhaps the findings could be related to issues of institutional mission (i.e., community colleges and public institutions valuing access) and selectivity (Attewell, Lavin, Domina, & Levey, 2006) and/or the "sorting" function of remediation that may track students into vocational programs (Bettinger & Long, 2004). Future research is recommended to explore the role of institutional type in supporting Latina/o students who enroll in developmental coursework.

Although present findings identified several student and institutional levels associated with successful math remediation for Latina/o students, much work remains to be done. It is notable that very few of the variables that have been previously found to be related to successful math remediation among all racial/ethnic groups (e.g., gender, age, first-generation college status, high school GPA) were significant for a national sample of Latina/os in this study. Additional quantitative work is therefore recommended to be able to better predict success for this growing and arguably overlooked and undervalued group of students. Results of the present study would suggest there is a crucial need to study Latina/o students who have the highest remedial need, as it remains unclear why students who place in the lowest levels of remediation do not successfully complete college-level courses (Bahr, 2010).

We also recommend work to understand the developmental and college-level classroom experiences of Latina/o developmental students. For instance, prior work by Hagedorn et al. (1999) would suggest that students who do not require remediation report more positive perceptions of their instructors when compared with developmental students. However, there is little qualitative work to explain how or why Latina/o remedial students may perceive faculty or the college experience more generally, differently than their peers. Related to this, Nora and colleagues' (i.e., Nora & Garcia, 1999) work would suggest that students' negative attitudes toward remediation may contribute to negative outcomes, but additional work is needed to understand whether and why this may be the case for Latina/o students in particular. Research by Acevedo-Gil et al. (2015) refers to placement in developmental education as a form of

"academic invalidation" (p. 109) that negatively affects students' beliefs in themselves as capable and successful college students. While their work offers a start to better understanding the experiences of Latina/o students in developmental education, we suggest more qualitative research to better understand Latina/o students' pathways through developmental math coursework. Finally, research is recommended to explore the role of broader college experiences, such as discrimination, negative climate, and stereotype threat as barriers to success for Latina/o students in and outside of math, both at the developmental and credit-bearing levels.

Implications for Policy and Practice

Results of the present study have direct implications for policy and practice by providing means of targeting developmental students who are at risk of not successfully remediating. Findings are also relevant to initiatives designed to retain Latina/o students' interest and participation in STEM fields as college-level math can serve as a "gatekeeper" to student access to STEM majors. To begin with, results highlight the importance of targeting efforts toward Latina/o students who require the most remediation, as this group of students was found across the models to be the least likely to successfully remediate. Findings support the value of considering alternative approaches to remediation (Levin & Calcagno, 2008) that show evidence of improving progress through multiple levels of developmental education, such as accelerated programs, mixed delivery methods, or self-paced instruction (see Rutschow & Schneider, 2011).

Present findings also highlight the importance of institutional, state, and federal policy that provides additional financial support to Latina/o students. Notably, one third of the national sample of Latina/o students who enrolled in math remediation received no form of financial aid, including grants, loans, or other forms of support. It is assumed that a lack of financial support may serve as a connected barrier to low-income and/or minority students (Leisenring, Santos, & Orfield, 2011) who enroll in developmental courses, as remedial-level courses do not typically count toward a certificate or degree and result in additional educational costs and forgone earnings (Bailey & Cho, 2010; Hughes & Scott-Clayton, 2011; Levin & Calcagno, 2008). Findings also bring attention to the importance of providing Latina/o developmental students' academic support outside of class that encourages interactions between students, faculty, and peers (Merisotis & Phipps, 2000), such as mentoring, "intrusive" advising, and/or supplemental instruction. Finally, our finding that one of the obstacles to completing college-level math is low attempt rates is consistent with recent findings by Fong et al. (2015). It is unclear why a sizable number of Latina/o students who successfully passed developmental math did not subsequently enroll in a college-level math course. It is possible that students may not have understood the required course sequence or switched majors to a vocational program or liberal arts degree that did not require college-level math. Additional research is suggested to examine the barriers/obstacles Latina/o students face in transitioning from developmental to college-level math courses.

Appendix

Description of Variables and Measures.

Variable name	Description and coding
Student-level variables	
Sociodemographic and precollege variables	
Gender	Binary variable coded 0 as female 1 as male
Age	Continuous variable representing students' age in 2003-2004 (range = 17-23)
Ethnic subgroup	Four-category dummy variable representing students' ethnic subgroup ([a]Mexican American or Chicano, Cuban, Puerto Rican, Other, or Mixed Latino origin)
First-generation status	Binary variable coded 0 when neither parent earned a college degree and 1 for continuing generation college students
High school GPA	Five-category dummy variable representing a range of high school GPA ([a]less than 2.0, 2.0-2.4, 2.5-2.9, 3.0-3.4, 3.5-4.0)
Highest math course taken	Four-category dummy variable indicating the highest mathematics course taken during high school ([a]Algebra II or lower, Trigonometry and Algebra, Pre-calculus, Calculus)
College-level credit	Binary variable coded 0 did not earn college-level credits during high school or 1 did earn college-level credits
Degree expectations	Four-category dummy variable representing students' highest degree expectation in 2003-2004 ([a]less than a bachelor's degree, bachelor's degree, master's degree, or post-bachelor certificate, doctoral or professional degree)
Academic experiences and pull factors	
Developmental math need	Continuous variable representing the number of developmental math courses taken (range = 0-4.0)
Amount worked off campus	Three-category dummy variable representing the amount of time students' worked (excluding work-study) during the first year of college ([a]worked full-time, worked part-time, did not work)
Amount of financial aid	Four-category dummy variable representing a range of financial aid received from all sources in 2003-2004 ([a]no aid received, less than US$2,500, between US$2,500 and US$4,999, between US$5,000 and US$9,999, more than US$10,000)
Enrollment intensity	Binary variable coded 0 enrolled college part-time or a mix of part and full-time through 2009 and 1 enrolled exclusively full-time
Academic support	Composite score calculated from three BPS items (α = .925): (a) Frequency a student met with faculty informally, (b) frequency of talking with faculty outside of class, and (c) frequency of participating in study groups (range = 0-2 representing the amount of support received)

(continued)

Appendix (continued)

Variable name	Description and coding
Stopout	Binary variable coded 0 stopped out at any institution through 2009 or 1 did not stopout of college
Developmental English	Binary variable coded 0 enrolled in developmental English coursework in 2003-2004 or 1 did not enroll in one or more developmental English courses
Institutional-level variables	
Institutional level	Binary variable coded 0 for institutions that are less than or 2-year institutions and 1 for 4-year institutions
Institutional type	Binary variable coded 0 for private institutions and 1 for public institutions
Enrollment size	Average total enrollment at the institution (range = 75-47,952)
Percent Latina/o	Percent student enrollment in 2003-2004 classified as Latina/o (range = 1-100)
% Students received federal aid	Percent of students who received federal grant aid in 2003-2004 (range = 0-100)
Outcomes—Successful remediation	
Passed developmental math	Did not pass all developmental math courses taken = 0, successfully passed all courses taken = 1
Enrolled in college-level math	Did not enroll in a college-level math course within 6 academic years = 0, successfully enrolled in a college-level math course within 6 years = 1
Passed college-level math	Did not pass a college-level math course within 6 academic years = 0, successfully passed a college-level math course = 1

[a]Denotes reference category.

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Note

1. All raw data are rounded to the nearest 10 per Institute of Education Sciences (IES) guidelines.

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