The Aftermath of Remedial Math:
Investigating the Low Rate of Certificate Completion among Remedial Math Students

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ABSTRACT

Nationally, a majority of community college students require remedial assistance with mathematics, but comparatively few students who begin the remedial math sequence ultimately complete it and achieve college-level math competency. The academic outcomes of students who begin the sequence but do not complete it are disproportionately unfavorable: most students depart from the community college without a credential and without transferring to a four-year institution. Interestingly, however, many of these students continue to attend the community college after they exit the remedial math sequence, sometimes for an extended period. One is led to ask, then, why students who do not complete the sequence generally are not finding their way to an alternative credential objective, such as a vocational certificate, that does not require college-level math competency. In this study, I explore three possible answers to this question, including difficulty navigating to the alternative credential, declining participation in the community college, and declining academic performance. I find that all three of these explanations contribute (to varying degrees) to explaining the low rate of certificate completion among remedial math students who do not achieve college-level math competency.

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INTRODUCTION

Research on remedial mathematics in community colleges continues to reveal a troubling state of affairs. Nationally, the majority of first-time community college students — about two-thirds — require remedial math assistance (Bailey, Jeong & Cho, 2010). Yet, nearly three-fourths of the students who begin the remedial math sequence ultimately do not complete a college-level math course successfully (Bahr, in press; Bailey, 2009). Unfortunately, students who begin the remedial math sequence but do not complete it are very likely to leave college without a credential and without transferring to a four-year institution (Bahr, 2008, 2010a). Accordingly, Cullinane and Treisman (2010) describe remedial education as "not an entryway but a burial ground for the aspirations of myriad community college students seeking to improve their lives through education" (p. 2).

Interestingly, however, the evidence indicates that students who drop out of the remedial math sequence without achieving college-level competency often remain enrolled in the community college after their last math course, sometimes for an extended period of time (Bahr, 2010b, in press; Perry, Bahr, Rosin & Woodward, 2010). In other words, there is a seeming contradiction between (1) the fact that the students who do not complete the remedial math sequence often continue in the community college for a number of semesters after their exit from the sequence and (2) the fact that these students only rarely leave the community college with any kind of credential. One is led to ask, what are students doing between their premature exit from the remedial math sequence and their eventual departure from the community college? Why are these students not finding their way to a credential program that has lower math requirements, such as a vocational certificate?

The objective of this study is to begin to deconstruct how students who drop out of the remedial math sequence without achieving college-level competency, but remain enrolled in the community college after their last math course, are using the community college before and after their participation in math. Specifically, I seek to understand how the course-taking and enrollment behavior of these students in the period after their exit from the remedial sequence (i.e., the *after-math* period) differs from their prior course-taking and enrollment behavior and from that of students who achieve college-level math competency. To accomplish this objective, I use data from the National Center for Education Statistics' National Education Longitudinal Study (NELS) and Postsecondary Education Transcript Study (PETS) to estimate the prevalence of this pattern of exiting the remedial math sequence without achieving college-level math competency but continuing to enroll in the community college. I then use data from the California Community College (CCC) system to estimate relationships between selected aspects of students' course-taking and enrollment behavior in the after-math period, their prior course-taking and enrollment behavior, and their highest level of math achievement, while controlling for other relevant variables. The focal course-taking and enrollment behaviors, which were selected based on reasoned inferences from the literature, include vocational course-taking, mean course credit load, and successful course completion.

BACKGROUND

It is unquestionably true that assisting every community college student to achieve college-level math competency is a highly desirable goal, benefiting both the students themselves and society as a whole. A number of current efforts are directed towards restructuring the remedial math sequence in community colleges and improving remedial math instruction so that a greater percentage of students are able to navigate it successfully (e.g.,

Bautsch, 2011; Biswas, 2007; Bryk & Toch, 2012; Cullinane & Treisman, 2010; Grubb, 2010; Perry, et al., 2010; Sheldon & Durdella, 2010). In fact, discussions about how to improve remediation in community colleges have been ongoing for some time (e.g., Bailey, 2009; Grubb & Cox, 2005; Levin & Calcagno, 2008; Perin, 2002; Waycaster, 2001). However, regardless of the success of current or future efforts to improve the remedial math sequence, inevitably some students will begin the sequence but not complete it. At present, this is the case for the majority of community college students who begin the remedial math sequence (Bahr, in press; Bailey, et al., 2010).

One would hope that students who depart from the remedial math sequence without achieving college-level math competency would be able to identify and complete an alternative goal that does not require college-level competency in math. In fact, most community colleges offer an educational track that results in a marketable credential but that usually does not require college-level math competency, namely the vocational certificate (Carnevale, Rose & Hanson, 2012). Although the name applied to this credential varies from college to college (e.g., career certificate, certificate of completion), as do the specific requirements for earning the credential, a vocational certificate generally represents the successful completion of a defined program of college coursework in a particular vocational field. Unlikely an associate's degree, however, the vocational certificate typically does not require the completion of general educational requirements, including college-level math and college-level English courses. As an example, American River College in Sacramento, California, offers more than 120 vocational certificates in fields as diverse as automotive technology, business, culinary arts, database management, elder care, fashion design, and geographic information systems, to name just a few (American River College, 2009). Although some of the vocational certificate programs require courses for

which college-level math competency is an explicit prerequisite or recommended preparation, most do not. Hence, a vocational certificate is a viable alternative credential for students who do not complete the remedial math sequence.

The evidence suggests that vocational certificates have significant labor-market value (Belfield & Bailey, 2011; Carnevale, et al., 2012). For example, Dadgar and Weiss (2012), using data from Washington, found that long-term certificates — those requiring one full-time year or more to complete — produced gains in earnings, a higher likelihood of being employed, and more hours worked per week among employed individuals. The labor market returns of short-term certificates — those requiring less than one-full-time year to complete — were found to be less compelling, but short-term certificates in certain fields did produce gains in earnings. Jepsen, Troske, and Coomes (2009) found similar results using data from Kentucky, though they found that even short-term certificates produce a higher likelihood of employment.

Yet, by and large, the hope that remedial math students who do not complete the remedial sequence will leave the community college with a marketable credential, such as a vocational certificate, is not being realized. More than four-fifths of these students depart from the community college without a credential and without transferring to a four-year institution (Bahr, 2008, 2010a). Given that many remedial math students who do not complete a college-level math course nevertheless persist in college after exiting the remedial sequence (Bahr, 2010b, in press; Perry, et al., 2010), one is led to ask why these students are not shifting their focus to, and ultimately earning, a vocational certificate prior to departing from college. The extant literature provides a number of hints concerning potential explanations, and I consider three likely possibilities in this study.

First, recent work has drawn attention to the difficulty experienced by many community

college students with navigating through the community college, which is a result in part of the great flexibility offered to students in terms of the academic goals that they pursue and the timeline on which they pursue those goals (Bahr, 2011a; Moore & Shulock, 2011; Rosenbaum, Deil-Amen & Person, 2009; Scott-Clayton, 2011). In light of this observation, one might suppose that students who depart from the remedial math sequence without achieving college-level math competency simply are not adjusting their educational plans to account for the change in their level of math achievement and, consequently, not adjusting their course-taking behavior in the after-math period. In other words, the most logical place for remedial math students to direct their course-taking if they do not complete a college-level math course is vocational fields, but misunderstanding or confusion associated with navigating the community college may stall this redirection of academic effort. If students who do not complete the remedial math sequence are not making necessary adjustments in their academic plans, one would expect to find no change in their likelihood of enrolling in vocational coursework during the after-math period relative to their prior participation in vocational coursework.

As a second, though not mutually exclusive, possibility, it is clear that students use the community college in a variety of ways to meet an array of ends, and these differing uses of the community college are demonstrated through divergent course-taking and enrollment patterns (e.g., Bahr, 2010c, 2011b). One conceptualization of variation in community college students' course-taking and enrollment patterns focuses on students' accumulation of course credit over time (e.g., Marti, 2008). Within this conceptualization, one common pattern identified by Marti (2008) is marked by a downward trend in semester-by-semester accumulation of course credit — a group that he described as *long-term decliners*.

As it pertains to the questions addressed in this study, it may be the case that remedial

math students who exit the remedial math sequence without achieving college-level math competency are disproportionately likely to exhibit long-term declining behavior. Although, on the face, this assertion may seem to be pure conjecture, in fact it could explain both the failure to achieve college-level math competency and the failure to earn a credential prior to departing from college. That is, some students' rate of progress (Bahr, 2009a) may be slowing progressively as their time in the community college lengthens until they first stop taking math courses and then eventually drop out of college altogether. If that were true, one would expect to find that the average course credit load of students who do not complete the remedial math sequence is significantly lower in the after-math period that it was prior to exiting the remedial math sequence. Furthermore, a downward trend in participation in the community college could negate the benefit of a shift to vocational course-taking in the after-math period, if such a shift is occurring, preventing even students who make the necessary adjustment in their academic trajectory from completing a vocational certificate prior to departing from college.

Finally, either separately or in conjunction with the previous propositions, it may be the case that students who exit the remedial math sequence without completing a college-level math course are disproportionately likely to be experiencing a downward trend in their academic performance. Evidence of this possibility may be found in Bahr's (2011b) study of the relationship between students' course-taking and enrollment patterns and their participation in remedial math. In particular, Bahr found that nearly one quarter of remedial math students in community colleges fit the course-taking and enrollment profile that he described as *experimental* — students who typically enroll in a part-time course load but who fail to complete successfully the majority of their courses during their comparatively short time in the community college. As with the possibility of overrepresentation of long-term declining behavior among

unsuccessful remedial math students, overrepresentation of declining academic performance could explain both the failure to complete the remedial sequence and the fact that students who do not complete the remedial sequence are unlikely to earn a credential prior to departing from college. If declining academic performance were part of the reason for the low rate of certificate completion among remedial math students who do not complete a college-level math course successfully, one would expect to find that these students have a lower average rate of course success in the after-math period, relative to their prior course success rate.

In sum, I consider three possible explanations for the low rate of vocational certificate completion among students who exit the remedial math sequence without achieving college-level math competency, including difficulty with navigating to the alternative credential, declining participation in the community college as measured by average course credit load, and declining academic performance as measured by course success rate. I test each of these possibilities by examining the relationship between students' behavior after exiting the remedial math sequence (i.e., their after-math behavior), their corresponding behavior prior to exiting the remedial math sequence, and their highest level of math achievement. In each case, I seek to answer two questions:

1. On average, does students' behavior in the period of time after exiting the remedial math sequence differ from their prior behavior, and, if so, in what direction?

2. If there is a difference in after-math behavior, does this difference depend to some extent on how far through the remedial math sequence a student progressed prior to exiting the sequence?

DATA, MEASURES, AND METHODS

Data Sources

I draw on two sources of data to answer the questions posed in this study. The first source is the National Educational Longitudinal Study (NELS:88/00) and the associated Postsecondary Education Transcript Study (PETS). Both studies were conducted by the National Center for Education Statistics (NCES) of the U.S. Department of Education. The NELS data constitute a nationally representative sample of eighth-grade students in the spring of 1988. These students were surveyed first in 1988, and then again in 1990, 1992, 1994, and 2000. The companion PETS dataset includes transcript records for each postsecondary institution attended.

I use the NELS/PETS data to estimate on a national scale how frequently community college students exit the remedial math sequence without achieving college-level math competency yet remain enrolled in the community college (i.e., the prevalence of remedial math non-completing persisting students). Unfortunately, the small number of community college students in the NELS/PETS data restricts the utility of these data for the larger analytical purpose of deconstructing students' course-taking and enrollment behavior after exiting the remedial math sequence.

The second source is the database maintained by the Chancellor's Office of the California Community Colleges (CCC). The CCC system database includes detailed transcript records, as well as demographic measures, financial records, records of credential awards, and the like, for all of the community college students in California's 112 community colleges. The large number of student records available in these data makes them an excellent choice for the analytical work of deconstructing students' course-taking and enrollment behavior after their exit from the remedial math sequence, but caution must be exercised in generalizing findings to

community college systems in other states.

Analytical Cohorts

As it pertains to the CCC system database, I focus specifically on the fall 2002 first-time student cohort in the 105 semester-based community colleges that were in operation in 2002. I defined this cohort to include students whose first term of enrollment in for-credit coursework was the fall 2002, who were not concurrently enrolled in high school in the fall 2002, who did not transfer college credit into the system at entry, who did not have a postsecondary degree at entry, who had not enrolled in a four-year institution within at least the previous five years, and who reported a valid social security number. The last criterion (a valid social security number) was necessary to determine the first term of for-credit enrollment in the system and to identify prior enrollments in four-year institutions. This cohort includes 190,637 students. The course-taking and enrollment behavior of these students was observed across the system, regardless of students' decisions to transfer laterally between community colleges (Bahr, 2009b, 2012), through the summer term of 2010. . I then restricted the cohort to those students who remained in the system for at least one semester after their first semester of attendance in the fall 2002 and whose first non-vocational math course was remedial in nature, resulting in a final analytical cohort of 79,545 students.

The analytical cohort from the NELS/PETS data was defined to parallel the cohort selected from the CCC system database, focusing on the fall 1992 first-time students in semester-based community colleges whose first non-vocational math course was remedial in nature and who remained in the community college for at least one semester after their first semester of attendance. The final analytical cohort for the NELS/PETS data includes 570 students whose

course-taking and enrollment behavior was observed through the spring term of 2001.[1]

Analytical Periods

The focus of this study is change in students' course-taking and enrollment behavior in the period of time after they exit the remedial math sequence — *the after-math period* — relative to their behavior between college entry and remedial math exit. Following Bahr's (in press) work, I defined remedial math to include all non-vocational math courses of a skill-level less than college algebra. In order from lowest skill to highest skill, remedial math includes arithmetic, pre-algebra, beginning algebra, intermediate algebra, and geometry, of which the latter two are parallel courses and of equivalent relative skill. College-level math includes college algebra, statistics, trigonometry, and all math courses of greater skill, such as pre-calculus, calculus, differential equations, linear algebra, and the like.

The semester in which a student exits the remedial math sequence is operationalized as the semester of a student's *first* successfully completed college-level math course or, in the absence of a successfully completed college-level math course, the semester of a student's last attempted remedial or college-level math course.[2] A successful math course enrollment is one resulting in a grade of A, B, C, Credit, or Pass.

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[1] Reported sample size was rounded to nearest ten, per NCES guidelines.

[2] The one exception to this rule is students who "double-back" in the remedial math sequence after completing a remedial math course successfully. Imagine, for example, a student who completed beginning algebra successfully (two levels below college-level math), enrolled in an arithmetic course (four levels below college-level math), completed arithmetic successfully, and then stopped taking math courses altogether. The student's semester of exit from the remedial math sequence would be the semester in which he/she completed beginning algebra because it was the students' highest-skill *successfully-completed* math course. However, if the student enrolled in beginning algebra, failed to pass the course, enrolled in arithmetic, passed arithmetic, and then stopped taking math courses, the student's semester of exit from the remedial math sequence would be the semester in which he/she enrolled in arithmetic. Such instances of students "doubling-back" after completing a higher-level remedial math course successfully are very rare in the data employed in this study.

In some cases, the semester of a student's exit from the remedial math sequence also was the student's last semester of enrollment in the community college system. By definition, such students did not have an *after-math period* and, therefore, were excluded from the analyses that addressed the period of time after exiting the remedial math sequence. It also is possible that the semester of a student's exit from the remedial math sequence corresponds with the last semester observed in the data (summer 2010 for the CCC data; spring 2001 for the NELS/PETS data), which is a problem of censoring. However, this correspondence occurred only very rarely due to the lengthy observation period for both of the analytical cohorts employed in this study (ten years for the CCC analytical cohort; nine years for the NELS/PETS analytical cohort).

Dependent Variables

I constructed three dependent variables for this study. The first two are course-level variables, specifically whether a given for-credit course taken by a student in the after-math period was vocational in nature and whether a given for-credit course taken in the after-math period was completed successfully (grade of A, B, C, Credit, or Pass). To construct these variables, I identified the first semester of enrollment following exit from the remedial math sequence for all students who continued in the community college after exiting remedial math. I then coded all courses that were taken in this semester or a subsequent semester as vocational (= 1) or not (= 0) and, separately, as completed successfully (= 1) or not (= 0). The vocational nature of a course was determined using the six-digit system in California's Taxonomy of Programs (Chancellor's Office, 2009). For the purpose of determining whether a course was completed successfully or not, grade records of "withdrawal" were treated as unsuccessful outcomes and coded as zeros.

The third dependent variable is mean course credit load in regular semesters after exiting

12

the remedial math sequence. I constructed this variable by calculating the total number of credits attempted by a student in fall and spring semesters during the after-math period, and then dividing this total by the number of fall and spring semesters in the after-math period in which a student enrolled in any coursework. Summer terms were excluded because even full-time students tend to enroll in lower course credit loads during these terms, leading to depressed values on this measure relative to students who did not enroll in coursework during the summer.

Independent Variables

The focal independent variables in this study are similar to the dependent variables but address the period of time between college entry and remedial math exit, as opposed to the period of time after exiting remedial math. The first is the proportion of non-math, for-credit courses taken by a student during this period that were vocational in nature. This measure was calculated by identifying the semester in which a student exited the remedial math sequence, dropping all courses that were attempted by the student after exiting the remedial math sequence, dropping all remedial and college-level math courses that were attempted by the student, and then calculating the proportion of the remaining courses that were vocational in nature, again using the California Taxonomy of Programs to determine vocational status.

Math courses were excluded from the calculation of this independent variable to avoid confounding vocational course-taking with mean course credit load. As a hypothetical example, consider that students who consistently attempted a half-time (six-credit) course load and consistently enrolled in math rarely would have a proportion of vocational courses greater than 0.5 (i.e., one three-credit math course and one three-credit vocational course), while students who enrolled in a full-time (twelve-credit) load could have a greater proportion of vocational courses simply due to their greater course load (e.g., one three-credit math course and three

three-credit vocational courses). Eliminating math courses from the calculation of this variable allowed both part-time and full-time students to have a possible range of zero to one on the measure of proportion of vocational courses.

The second of the focal independent variables is the proportion of non-math, for-credit courses attempted by a student in the period between college entry and remedial math exit that were completed successfully (grade of A, B, C, Credit, or Pass). This measure was calculated in the same manner as the proportion of vocational courses with the exception that this measure addresses a successful grade outcome rather than the vocational nature of the course.

The last of the focal independent variable is students' mean course credit load in regular (fall and spring) semesters in the period between college entry and remedial math exit. This measure was calculated in a manner comparable to that of students' mean course credit load in the after-math period. Note that, unlike the proportion of vocational courses and proportion of courses completed successfully, the calculation of this independent variable *includes* remedial and college-level math courses in which a student enrolled in the period between college entry and remedial math exit.

In addition to the three focal independent variables, I include in the analyses a student's point of entry to the remedial math sequence, point of exit from the remedial math sequence, demonstrated writing competency at exit from the remedial math sequence, self-reported academic goal at college entry, and whether or not a student completed a credential during the period of time between college entry and remedial math exit. Point of entry to the remedial math sequence was operationalized as the skill-level of a student's first remedial math course, while point of exit was operationalized as the skill-level of a student's highest-skill, successfully-completed math course, if any. Similarly, writing competency at exit from the remedial math

sequence was operationalized as the skill-level of a student's highest-skill, successfully-completed writing course (Bahr, in press) during the period of time between college entry and remedial math exit, if any. The completion of a credential prior to exiting remedial math includes certificates and associate's degrees. A total of 5,735 students (7.2%) in the analytical cohort selected from the CCC system database completed a credential prior to exiting the remedial math sequence.

Methods of Analysis

I employed two distinct statistical methods in this study, depending on the nature of the dependent variable addressed. In the case of the two course-level, dichotomous dependent variables, I used a random-intercept (multilevel) logistic regression model in which courses were nested within students. The dependent variable that addresses whether a given course attempted in the after-math period was vocational or not was regressed on the proportion of non-math courses attempted by a student in the period prior to exiting the remedial math sequence that were vocational in nature, the square root of the proportion of vocational courses, point of exit from the remedial math sequence, the interaction of proportion of vocational courses and point of exit, point of entry to the remedial math sequence, the highest-level writing course completed successfully by a student prior to exiting the remedial math sequence, student's self-reported academic goal at college entry, and whether or not a student completed a credential prior to exiting the remedial math sequence. The dependent variable that addresses whether a given course attempted by a student in the after-math period was completed successfully or not was treated in the same manner, except for the substitution of the corresponding independent variable.

The dependent variable that addresses mean course credit load in the after-math period

was analyzed using a simpler ordinary least squares linear regression model. Otherwise, though, the analysis was handled in the same manner as the previous two dependent variables, using the same set of independent variables.

ANALYSIS

Continuing in the Community College After Exiting the Remedial Math Sequence

To estimate the frequency with which students exit the remedial math sequence without achieving college-level math competency yet continue in the community college, I present in Tables 1 and 2 the percentage of students who continued in the community college after exiting remedial math by point of entry to remedial math and achievement of college-level math competency. Table 1 provides national estimates from NELS:88/00 and the associated PETS data, while Table 2 provides the figures for the CCC system. Recall that both analytical cohorts were confined to students who continued in the community college for at least one semester after their first semester of attendance. Note also that small absolute (unweighted) cell sizes required that students in the NELS data who began the remedial math sequence with pre-algebra and those who began with basic arithmetic be collapsed into a single category.

[insert Table 1 about here]

[insert Table 2 about here]

One observes in Tables 1 and 2 that a majority of students who exited the remedial math sequence without achieving college-level math competency continued in the community college: three-fifths (60.1%) of students nationally and more than two-thirds (67.5%) of students in California. The high prevalence of this pattern of behavior holds for all points of entry to remedial math, from basic arithmetic to intermediate algebra and plane geometry. Thus, exit from remedial math without achieving college-level math competency is not equivalent to

16

departure from college. Still, we know that most of the remedial math students who do not complete a college-level math course also do not go on to complete credentials (Bahr, 2008, 2010a). What, then, are these students doing between exit from the remedial math sequence and departure from college?

Duration of Enrollment Before and After Exiting the Remedial Math Sequence

In order to understand how students' use their time in the community college after exiting the remedial math sequence, one first needs a sense of the *length* of time that remedial math students spend in the community college and how this time is distributed between the period *before and during* their participation in math and the period *after* their participation in math. To address this issue, I focused on the data from the CCC system. I measured time as a count of the number of semesters (fall, spring, and summer) in which a student attempted any coursework.

In Table 3, I present the mean number of semesters that students enrolled in the community college between entry to college and exit from the remedial math sequence, by point of entry to remedial math and achievement of college-level math competency. Table 4 addresses the corresponding figures for the period of time after exiting remedial math — the mean number of semester that students remained in the community college after exiting remedial math, if they continued in the system. One observes here that students who did not complete a college-level math course spent an average of 5.0 semesters in the community college between college entry and remedial math exit (Table 3). The two-thirds of these students who continued in the community college after exiting remedial math remained in college for an average of 3.2 *additional* semesters (Table 4).

[insert Table 3 about here]

[insert Table 4 about here]

Although three semesters would seem to be a sufficient amount of time to complete a vocational certificate under most circumstances, as noted earlier the evidence indicates that students who do not achieve college-level math competency are very likely to leave the community college without a credential and without transferring to a four-year institution (Bahr, 2008, 2010a). To illustrate this problem with these data, I present in Table 5 the distribution of long-term academic outcome by achievement of college-level math competency for students who continued in the community college after exiting remedial math.

[insert Table 5 about here]

One observes in Table 5 that students who did not achieve college-level math competency but continued in college were much more likely to complete a vocational certificate than were their counterparts who achieved college-level math competency (4.4% versus 0.8%). Nevertheless, nearly 84% of students who did not achieve college-level math competency left the community college without a credential and without transferring to a four-year institution. In other words, most remedial math students who did not achieve college-level math competency, but who persisted in the community college after exiting remedial math, left the community college with nothing to show for their time invested in postsecondary education other than accumulated course credits.

Credit Accumulation Before and After Exiting the Remedial Math Sequence

Duration of enrollment provides one perspective on students' time in the community college before and after exiting the remedial math sequence, but credit accumulation may provide a different perspective. Therefore, I calculated the mean number of credits earned by students during the period prior to exiting the remedial math sequence (Table 6) and during the period after exiting the remedial math sequence if they continued in the system (Table 7).

[insert Table 6 about here]

[insert Table 7 about here]

Overall, remedial math students who did not achieve college-level math competency earned substantially fewer credits, on average, during both windows of time than did their counterparts who completed a college-level math course. Still, these students earned an average of 27.8 credits prior to exiting remedial math — a sufficient number of credits for many long-term vocational certificate programs. Moreover, students who exited the remedial math sequence without achieving college-level math competency, but continued in the community college, earned an average of 13.4 additional credits during the after-math period, which is sufficient number of credits in itself to earn some short-term certificates, but not enough for the long-term certificate programs that carry the superior labor-market benefits (Carnevale, et al., 2012; Dadgar & Weiss, 2012; Jepsen, et al., 2009).

While illuminating in their own right, these figures also provide some clues about why students who exit the remedial math sequence without achieving college-level math competency are not completing vocational certificates at a higher rate. Although these figures cannot speak to the possible navigational problem discussed earlier, the fact that unsuccessful remedial math students are remaining enrolled for an average 3.2 semesters after exiting the remedial math sequence but earning an average of only 13.4 credits during this period, indicates that they either are taking very low course credit loads in the after-math period, experiencing a very low rate of course success, or both.

Vocational Course-Taking in the After-Math Period

I proposed three possible explanations for why students who exit the remedial math sequence without achieving college-level math competency are not completing vocational

certificates at a much higher rate. I described the first explanation as a problem of navigation: students who do not complete the remedial math sequence may not recognize that an adjustment to their academic trajectory and course-taking is necessary. If a navigational problem is part of the explanation for the low rate of vocational certificate attainment among remedial math students who do not achieve college-level math competency, one would expect to find little or no increase in vocational course-taking in the after-math period relative to vocational course-taking prior to exiting remedial math.

To test this explanation, I used a random-intercept logistic regression model (courses nested within students) to analyze the probability that any given course taken in the after-math period was vocational in nature as a function of the proportion of vocational courses taken by a student prior to exiting the remedial math sequence (excluding all math courses from the calculation of this proportion), point of exit from the remedial math sequence, and a selection of other variables. The results are presented in Table 8, though they are difficult to interpret directly due to the quadratic and interaction terms. Therefore, I provide in Table 9 and Figure 1 the predicted probability that a given course taken in the after-math period was vocational as a function of the proportion of vocational courses prior to exiting the remedial math sequence and point of exit from the sequence. Note that 524 of the 58,039 remedial math students who continued in the community college after exiting the remedial math sequence were excluded from this portion of the analysis because they enrolled only in noncredit, ungraded, or dependent courses in the after-math period.

[insert Table 8 about here]

[insert Table 9 about here]

[insert Figure 1 about here]

In making sense of the Table 9 and Figure 1, it is important to note that a probability may be interpreted as a long-run proportion. Therefore, if one were to observe that a 0.20 proportion of vocational courses prior to exiting the remedial math sequence is associated with a 0.20 probability that any given course in the after-math period is vocational, one would conclude that there has not been a change in vocational course-taking in the after-math period relative to prior behavior. In contrast, if the same behavior prior to exiting the remedial math sequence is associated with a 0.40 probability that any given course in the after-math period is vocational, one would conclude that there has been an *increase* vocational course-taking in the after-math period.

With respect to the proposition tested here, the findings presented in Table 9 and Figure 1 are mixed. To explain, the range of typical values for proportion of vocational courses in the period prior to exiting the remedial math sequence is zero to 0.29 (the 25th and 75th percentiles, respectively).[3] Over this range, one observes that students who did not achieve college-level math competency experienced relative increases in the probability that any given course taken in the after-math period was vocational, but, at the upper end of the range of typical values, the increases are small. For example, students who exited the remedial math sequence at beginning algebra (two levels below college-level math) and had a 0.10 proportion of vocational courses prior to exiting the remedial math sequence (i.e., 10% vocational) are predicted to have a 0.26 probability that any given course attempted in the after-math period was vocational (i.e., 26% vocational), which is a meaningful relative increase. Comparable students who had a 0.30 proportion of vocational courses prior to exiting the remedial math sequence are predicted to have a 0.34 probability that any given course attempted in the after-math period was vocational,

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[3] The mean proportion of vocational courses in the period prior to exiting the remedial math sequence was 0.19.

which is only a small relative increase. Moreover, at or above a 0.40 proportion of vocational courses prior to exiting the remedial sequence, one observes a relative decline in the predicted probability of that any given course attempted in the after-math period was vocational.

In sum, over the range of typical values of prior vocational course-taking, it appears that students who did not achieve college-level math competency *are* shifting toward vocational coursework in the after-math period, though this shift is modest. On the other hand, students who exhibited a comparatively strong focus on vocational coursework prior to exiting the remedial math sequence tend to experience a relative decline in this focus in the after-math period.

Course Credit Load in the After-Math Period

The second proposed explanation concerns declining participation in the community college. Specifically, I proposed that students who exit the remedial math sequence without achieving college-level math competency may be more likely to be experiencing a downward trend in terms of their course credit load. To test this proposition, I used ordinary least squares linear regression to analyze mean course credit load in regular semesters (fall and spring, excluding summer) during the after-math period as a function of course credit load in regular semesters prior to exiting the remedial math sequence, point of exit from the remedial math sequence, and other variables. The results of this regression are presented in Table 10, and predicted values are provided in Table 11 and Figure 2. Note that 2,761 students were excluded from this portion of the analysis because they enrolled only in summer terms in the after-math period.

[insert Table 10 about here]

[insert Table 11 about here]

[insert Figure 2 about here]

If long-term declining behavior is part of the explanation for the low rate of vocational certificate completion among students who do not achieve college-level math competency, one would expect to find a decrease in mean course credit load in the after-math period relative to mean course credit load prior to exiting the remedial math sequence. The results presented Table 11 and Figure 2 support this proposition. Over the range of typical values of mean course credit load prior to exiting the remedial math sequence (9.0 to 13.3 — the 25th and 75th percentiles, respectively), students who did not achieve college-level math competency experienced significant relative decreases in their mean course credit load in the after-math period.[4]

In fact, over the range of typical values, *all* students tended to reduce their course credit load in the after-math period regardless of the point at which they exited the remedial math sequence. However, students who exited the remedial math sequence prior to achieving college-level math competency reduced their course credit load significantly *more* than did students who achieved college-level math competency. For example, a student who was carrying a full-time, twelve-credit load prior to exiting the remedial math sequence, and who exited the sequence at beginning algebra, is predicted to have a mean course credit load of 8.2 credits per semester in the after-math period. In contrast, a similar student who achieved college-level math competency is predicted to have a mean course credit load of 9.8 credits per semester in the after-math period. Only at very low course credit loads prior to exiting the remedial math sequence (fewer than six credits per semester) are relative increases observed in the predicted after-math course credit load.

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[4] The average value for mean course credit load in the period prior to exiting the remedial math sequence was 11.1.

Course Success in the After-Math Period

The last proposed explanation is that students who exit the remedial math sequence without achieving college-level math competency may be more likely to be experiencing a downward trend in their academic performance. To test this proposition, I analyzed the probability that any given course taken in the after-math period was completed successfully as a function of the proportion of *non-math* courses completed successfully by a student prior to exiting the remedial math sequence, point of exit from the remedial math sequence, and other variables. As with the analysis of vocational course-taking described earlier, I used a random-intercept logistic regression model to execute this analysis. The results are presented in Table 12. Predicted probabilities of success in any given course attempted in the after-math period as a function of course success rate prior to exiting the remedial math sequence and point of exit from the remedial math sequence are presented in Table 13 and Figure 3.

[insert Table 12 about here]

[insert Table 13 about here]

[insert Figure 3 about here]

Note that 2,118 students were excluded from this portion of the analysis because they had no valid course outcomes in for-credit courses prior to exiting remedial math (other than those associated with math course enrollments) or had no valid course outcomes in for-credit courses after exiting remedial math. Valid course outcomes include all letter grades, "Pass", "No Pass", "Credit", "No Credit", and "Withdrawal". Invalid course outcomes include "Incomplete" or a course grade that was not reported by the college (i.e., a true missing grade).

These results provide partial support for the proposition that students who exit the remedial math sequence without achieving college-level math competency are experiencing

24

declining academic performance. The range of typical values of course success rate in the period prior to exiting the remedial math sequence is 0.50 to 0.90 (the 25th and 75th percentiles, respectively).[5] Among students who exited the remedial math sequence three or four levels below college-level math or who did not complete successfully any remedial or college-level math courses, one observes a relative decline in the predicted probability of course success in the after-math period across the range of typical values of prior course success rate. For example, a student who exited the remedial math sequence at pre-algebra and had a 0.70 course success rate in the period prior to exiting remedial math (i.e., 70% success in courses) is predicted to have a 0.56 probability of completing successfully any given course attempted in the after-math period (i.e., 56% success in courses). In contrast, students who exited the remedial math sequence at one or two levels below college-level math are predicted to have a probability of course success in the after-math period that is similar to their prior rate of success or, at the upper end of the range of typical values, modestly lower than their prior rate of success. Students who achieved college-level math competency are predicted to have a probability of course-success in the after-math period that is relatively higher than their prior course success rate across nearly the whole range of typical values of prior course success rate. In sum, students who exited the sequence at the lower rungs of the remedial math ladder, or who did not complete any remedial or college-level math courses successfully, are disproportionately likely to be experiencing declining academic performance in the after-math period, relative to their prior performance.

DISCUSSION

One of the most significant challenges to current efforts to increase the rate at which community college students complete credentials is found at the intersection of the widespread

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[5] The mean course success rate in the period prior to exiting the remedial math sequence was 0.66.

need for remedial math assistance and the very low rate at which students are able to navigate the remedial math sequence successfully and achieve college-level math competency (Bahr, in press). The majority of community college students require remedial math assistance, but relatively few students who begin the remedial math sequence ultimately complete it (Bailey, et al., 2010). Students who do not complete the remedial math sequence are overwhelmingly likely to leave the community college without a credential (Bahr, 2008, 2010a).

Current efforts to solve this problem rightfully focus on improving the remedial math sequence and the delivery of remedial math instruction (e.g., Bautsch, 2011; Biswas, 2007; Bryk & Toch, 2012; Cullinane & Treisman, 2010; Grubb, 2010; Perry, et al., 2010; Sheldon & Durdella, 2010). There is little doubt that success in these efforts will improve the rate at which community college students complete credentials. However, we also can be certain that there always will be a fraction of students who exit the remedial math sequence without achieving college-level math competency. Currently, this fraction is a sizeable majority. Hence, while we should continue efforts to improving remedial math, we also need to direct attention to helping students who do not complete the remedial math sequence to identify and achieve alternative academic goals that do not require college-level math competency.

In the absence of college-level math competency, the most viable alternative credential in the community college is the vocational certificate — a credential that requires a comparatively short period of time to complete and that has demonstrated labor market value (Belfield & Bailey, 2011; Carnevale, et al., 2012; Dadgar & Weiss, 2012; Jepsen, et al., 2009). Yet, despite the fact that the majority of unsuccessful remedial math students continue in the community college after exiting the remedial math sequence, few complete a vocational certificate. In fact, as demonstrated in this study, more than two-thirds of students in California (three-fifths of

students nationally) who exit the remedial math sequence without achieving college-level math competency continue in the community college (for an average of about three semesters), but less than 5% of these students complete a vocational certificate.

In this study, I sought to determine why students who exit the remedial math sequence without achieving college-level math competency do not complete vocational certificates at a higher rate than is observed. I proposed three potential explanations, including a problem of navigation after exiting the remedial math sequence, declining participation in the community college, and declining academic performance.

To varying degrees, the evidence supports all three of these explanations. Remedial math students who do not achieve college-level math competency tend to have a significantly lower mean course credit load after exiting the remedial math sequence than they had prior to exiting the remedial math sequence, slowing their academic progress during the critical "make-or-break" after-math period. In addition, though unsuccessful remedial math students who had a typical (fairly low) concentration of vocational course-taking prior to exiting the remedial math sequence tend to increase this concentration modestly in the after-math period, they do not experience the wholesale shift toward vocational coursework in the after-math period that would be necessary for most students to complete a vocational certificate in their limited remaining time in the community college. Finally, students who exited the remedial math sequence at the lower rungs of the remedial math ladder, or who did not complete any remedial or college-level math courses successfully, are disproportionately likely to be experiencing an overall declination in their academic performance, which further hampers their already slow academic progress resulting from a low course credit load. In sum, there are at least three obstacles to the completion of vocational certificates by students who exit the remedial math sequence prior to

achieving college-level math competency: slow progress that is not directed fully toward necessary vocational coursework and, among students who exit the remedial math sequence well below college-level math, poor academic performance.

The question, of course, is what to do for students who exit the remedial math sequence without achieving college-level math competency to help them complete a credential before departing from the community college. The findings of this study suggest these students require unambiguous information and guidance concerning the availability and means of completing goals, such as a vocational certificate, that are realistic given their limited progress in mathematics (Grubb, 2001). In other words, students clearly need assistance to navigate the changes in the academic opportunity structure that are associated with their premature exit from the remedial math sequence.

This study also indicates that the combination of premature exit from the remedial math sequence and the low rate of vocational certificate completion may not be entirely a product of the remedial sequence itself. Specifically, the lower average course credit load and lower course success rate observed in the after-math period among students who did not complete the remedial math sequence suggests the possibility that students' premature exit from the remedial sequence may be a *consequence* of students' gradual departure or "slippage" from college, rather than a cause. In turn, this interpretation leads to a more tempered level of optimism about the potential impact of improving the remedial math sequence on community college students' rate of credential attainment. In other words, to the extent that attrition from the remedial math sequence is a result of a general "slippage" from college, characterized by a declining course credit load and declining academic performance, restructuring the remedial math sequence may not solve entirely either the problem of attrition from the sequence or the problem of

unsuccessful remedial math students departing college without a credential. Still one would hope that providing a clear alternative goal for students who do not achieve college-level math competency to pursue after exiting the remedial math sequence might bolster students' participation in college and improve the chances that these students will complete a credential prior to departing.

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Table 1: National estimate of the percentage of students who continued in the community college after exiting the remedial math sequence, by point of entry to the remedial math sequence and achievement of college-level math competency[1]

Point of Entry to Math	Did Not Complete College-Level Math	Completed College-Level Math	Both
interm. algebra or plane geom.	63.3%	84.1%	71.2%
	(90)	(40)	(130)
beginning algebra	59.7%	78.4%	62.8%
	(170)	(30)	(200)
basic arithmetic or pre-algebra	59.0%	73.0%	59.8%
	(220)	(20)	(240)
all points of entry	60.1%	80.8%	63.8%
	(480)	(90)	(570)

[1] Estimates are based on NELS:88/00 data and the associated PETS data and were weighted using F4F2PNWT. Reported cell sizes were rounded to nearest ten, per NCES guidelines.

Table 2: Percentage of students who continued in the CCC system after exiting the remedial math sequence, by point of entry to the remedial math sequence and achievement of college-level math competency (*N* = 79,545)

Point of Entry to Math	Did Not Complete College-Level Math	Completed College-Level Math	Both
interm. algebra or plane geom.	73.1%	90.2%	82.2%
	(8,211)	(9,332)	(17,543)
beginning algebra	69.6%	86.1%	74.6%
	(18,303)	(7,979)	(26,282)
pre-algebra	65.6%	82.3%	68.5%
	(14,385)	(3,033)	(17,418)
basic arithmetic	64.2%	82.6%	66.0%
	(16,525)	(1,777)	(18,302)
all points of entry	67.5%	87.0%	73.0%
	(57,424)	(22,121)	(79,545)

Table 3: Mean number of terms enrolled in the CCC system *between college entry and remedial math exit*, by point of entry to the remedial math sequence and achievement of college-level math competency (*N* = 79,545)

Point of Entry to Math	Did Not Complete College-Level Math	Completed College-Level Math	Both
interm. algebra or plane geom.	4.4	5.4	4.9
	(8,211)	(9,332)	(17,543)
beginning algebra	4.8	7.3	5.5
	(18,303)	(7,979)	(26,282)
pre-algebra	5.3	8.8	5.9
	(14,385)	(3,033)	(17,418)
basic arithmetic	5.1	9.8	5.6
	(16,525)	(1,777)	(18,302)
all points of entry	5.0	6.9	5.5
	(57,424)	(22,121)	(79,545)

Table 4: Mean number of terms enrolled in the CCC system *after exiting the remedial math sequence*, by point of entry to the remedial math sequence and achievement of college-level math competency ($N = 58,039$)[1]

Point of Entry to Math	Did Not Complete College-Level Math	Completed College-Level Math	Both
interm. algebra or plane geom.	3.4	4.9	4.3
	(6,005)	(8,422)	(14,427)
beginning algebra	3.3	4.1	3.6
	(12,743)	(6,866)	(19,609)
pre-algebra	3.1	3.8	3.2
	(9,430)	(2,495)	(11,925)
basic arithmetic	3.0	3.6	3.1
	(10,610)	(1,468)	(12,078)
all points of entry	3.2	4.4	3.6
	(38,788)	(19,251)	(58,039)

[1] Includes only those students who continued in the CCC system after exiting the remedial math sequence.

Table 5: Frequency distribution of long-term academic outcome for students who continued in the CCC system after exiting the remedial math sequence, by achievement of college-level math competency (*N* = 58,039)

Academic Outcome	Did Not Complete College-Level Math	Completed College-Level Math	Both
transfer with a credential	0.6%	34.5%	11.9%
	(244)	(6,643)	(6,887)
transfer without a credential	2.3%	27.2%	10.6%
	(902)	(5,233)	(6,135)
academic associate's degree	4.4%	11.6%	6.8%
	(1,725)	(2,234)	(3,959)
vocational associate's degree	4.3%	3.2%	4.0%
	(1,682)	(617)	(2,299)
vocational certificate	4.4%	0.8%	3.2%
	(1,726)	(158)	(1,884)
no credential and no transfer	83.8%	22.7%	63.5%
	(32,509)	(4,366)	(36,875)
total	100.0%	100.0%	100.0%
	(38,788)	(19,251)	(58,039)

Table 6: Mean number of credits earned in the CCC system *between college entry and remedial math exit*, by point of entry to the remedial math sequence and achievement of college-level math competency (*N* = 79,545)

Point of Entry to Math	Did Not Complete College-Level Math	Completed College-Level Math	Both
interm. algebra or plane geom.	25.9	48.5	37.9
	(8,211)	(9,332)	(17,543)
beginning algebra	27.9	62.2	38.3
	(18,303)	(7,979)	(26,282)
pre-algebra	29.0	72.9	36.7
	(14,385)	(3,033)	(17,418)
basic arithmetic	27.5	79.4	32.5
	(16,525)	(1,777)	(18,302)
all points of entry	27.8	59.3	36.5
	(57,424)	(22,121)	(79,545)

Table 7: Mean number of credits earned in the CCC system *after exiting the remedial math sequence*, by point of entry to the remedial math sequence and achievement of college-level math competency (*N* = 58,039)[1]

Point of Entry to Math	Did Not Complete College-Level Math	Completed College-Level Math	Both
interm. algebra or plane geom.	15.2	35.2	26.9
	(6,005)	(8,422)	(14,427)
beginning algebra	14.8	27.0	19.1
	(12,743)	(6,866)	(19,609)
pre-algebra	12.4	23.4	14.7
	(9,430)	(2,495)	(11,925)
basic arithmetic	11.5	21.2	12.6
	(10,610)	(1,468)	(12,078)
all points of entry	13.4	29.7	18.8
	(38,788)	(19,251)	(58,039)

[1] Includes only those students who continued in the CCC system after exiting the remedial math sequence.

Table 8: Results of the random-intercept logistic regression of vocational course enrollment in the after-math period on selected variables ($N_{students}$ = 57,515; $N_{courses}$ = 539,930)

	Coefficient	Std Error
Point of Entry to Math		
2 levels below college (vs. 1 level below college)	0.05*	0.02
3 levels below college (vs. 1 level below college)	0.07**	0.03
4 levels below college (vs. 1 level below college)	0.06*	0.03
Point of Exit from Math		
1 level below college (vs. college-level)	0.73***	0.05
2 levels below college (vs. college-level)	0.83***	0.05
3 levels below college (vs. college-level)	0.94***	0.07
4 levels below college (vs. college-level)	0.86***	0.07
none or vocational only (vs. college-level)	0.94***	0.04
Prior Proportion of Vocational Courses		
identity	-0.77***	0.24
identity * point of exit = 1 level below college	1.14**	0.39
identity * point of exit = 2 levels below college	1.73***	0.34
identity * point of exit = 3 levels below college	3.34***	0.44
identity * point of exit = 4 levels below college	2.91***	0.44
identity * point of exit = none or vocational only	3.59***	0.31
square root	2.05***	0.16
square root * point of exit = 1 level below college	-0.83**	0.29
square root * point of exit = 2 levels below college	-1.30***	0.26
square root * point of exit = 3 levels below college	-2.44***	0.35
square root * point of exit = 4 levels below college	-1.94***	0.35
square root * point of exit = none of vocational only	-2.51***	0.22
Highest-Skill Writing Course Completed Prior to Exiting Math		
1 level below college (vs. college-level)	-0.06*	0.03
2 levels below college (vs. college-level)	-0.07*	0.03
3 levels below college (vs. college-level)	-0.03	0.06
4 or 5 levels below college (vs. college-level)	-0.12	0.12
none or vocational only (vs. college-level)	-0.02	0.02
Academic Goal at College Entry		
transfer (vs. transfer + associate's degree)	-0.05	0.03
academic associate's degree (vs. transfer + associate's degree)	0.23***	0.03
vocational associate's degree (vs. transfer + associate's degree)	0.40***	0.06
vocational certificate (vs. transfer + associate's degree)	0.30***	0.06
other job-related (vs. transfer + associate's degree)	0.20***	0.03
personal development (vs. transfer + associate's degree)	0.05	0.04
remediation (vs. transfer + associate's degree)	0.16***	0.05
undecided (vs. transfer + associate's degree)	0.06**	0.02

missing (vs. transfer + associate's degree)		0.12*	0.05
Completed Credential Prior to Exiting Math			
yes (vs. no)		0.27***	0.04
Constant		-2.26***	0.03

*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$

Table 9: Predicted probability that any given course taken in the after-math period was vocational as a function of proportion of vocational courses prior to exiting remedial math and point of exit from remedial math (based on the estimates provided in Table 10)

Prior Proportion of Vocational Courses	Point of Exit from Math (Highest-Skill Math Course Completed Successfully)					
	College-Level Math	One Level Below College Math	Two Levels Below College Math	Three Levels Below College Math	Four Levels Below College Math	None or Vocational Math Only
0.00	0.10	0.18	0.20	0.21	0.20	0.21
0.05	0.14	0.24	0.24	0.23	0.23	0.22
0.10	0.16	0.26	0.27	0.25	0.25	0.24
0.15	0.18	0.28	0.29	0.27	0.27	0.26
0.20	0.19	0.30	0.30	0.29	0.30	0.28
0.25	0.20	0.32	0.32	0.31	0.32	0.31
0.30	0.21	0.33	0.34	0.33	0.34	0.33
0.35	0.22	0.35	0.36	0.36	0.37	0.36
0.40	0.23	0.36	0.37	0.38	0.39	0.39
0.45	0.23	0.38	0.39	0.41	0.42	0.41
0.50	0.24	0.39	0.40	0.43	0.45	0.44
0.55	0.24	0.40	0.42	0.46	0.47	0.47
0.60	0.25	0.41	0.44	0.49	0.50	0.50
0.65	0.25	0.42	0.45	0.51	0.53	0.53
0.70	0.26	0.44	0.47	0.54	0.55	0.56
0.75	0.26	0.45	0.48	0.57	0.58	0.59
0.80	0.26	0.46	0.50	0.59	0.61	0.62
0.85	0.27	0.47	0.51	0.62	0.63	0.65
0.90	0.27	0.48	0.52	0.64	0.65	0.68
0.95	0.27	0.49	0.54	0.67	0.68	0.70
1.00	0.27	0.50	0.55	0.69	0.70	0.73

Note: Assumes a student whose point of entry to remedial math was beginning algebra, whose highest-skill successfully-completed writing course was college composition, whose goal at college entry was upward transfer to a four-year institution in combination with an associate's degree, and who did not complete a credential prior to exiting remedial math.

Table 10: Results of the ordinary least squares regression of mean course credit load in the aftermath period on selected variables ($N_{students} = 55{,}278$)

	Coefficient	Std Error
Point of Entry to Math		
2 levels below college (vs. 1 level below college)	-0.40***	0.04
3 levels below college (vs. 1 level below college)	-0.64***	0.05
4 levels below college (vs. 1 level below college)	-0.76***	0.06
Point of Exit from Math		
1 level below college (vs. college-level)	1.47	1.70
2 levels below college (vs. college-level)	4.48**	1.54
3 levels below college (vs. college-level)	5.24**	1.77
4 levels below college (vs. college-level)	4.09*	1.61
none or vocational only (vs. college-level)	3.48**	1.31
Prior Mean Course Credit Load		
identity	0.06	0.10
identity * point of exit = 1 level below college	0.16	0.16
identity * point of exit = 2 levels below college	0.48***	0.15
identity * point of exit = 3 levels below college	0.62***	0.18
identity * point of exit = 4 levels below college	0.53**	0.17
identity * point of exit = none or vocational only	0.27*	0.12
square root	2.37***	0.69
square root * point of exit = 1 level below college	-1.47	1.05
square root * point of exit = 2 levels below college	-3.42***	0.95
square root * point of exit = 3 levels below college	-4.23***	1.13
square root * point of exit = 4 levels below college	-3.50***	1.04
square root * point of exit = none of vocational only	-2.61***	0.80
Highest-Skill Writing Course Completed Prior to Exiting Math		
1 level below college (vs. college-level)	0.32***	0.05
2 levels below college (vs. college-level)	0.22***	0.07
3 levels below college (vs. college-level)	0.22*	0.11
4 or 5 levels below college (vs. college-level)	0.16	0.24
none or vocational only (vs. college-level)	0.19***	0.04
Academic Goal at College Entry		
transfer (vs. transfer + associate's degree)	-0.04	0.05
academic associate's degree (vs. transfer + associate's degree)	0.05	0.07
vocational associate's degree (vs. transfer + associate's degree)	0.31**	0.11
vocational certificate (vs. transfer + associate's degree)	0.13	0.12
other job-related (vs. transfer + associate's degree)	-0.08	0.06
personal development (vs. transfer + associate's degree)	-0.02	0.07
remediation (vs. transfer + associate's degree)	0.23*	0.10
undecided (vs. transfer + associate's degree)	-0.04	0.04

missing (vs. transfer + associate's degree)	0.22*	0.09
Completed Credential Prior to Exiting Math		
yes (vs. no)	-2.07***	0.07
Constant	1.26	1.18

*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$

Table 11: Predicted mean course credit load in the after-math period as a function of mean course credit load prior to exiting remedial math and point of exit from remedial math (based on the estimates provided in Table 12)

| | **Point of Exit from Math (Highest-Skill Math Course Completed Successfully)** | | | | | |
Prior Mean Course Credit Load	College-Level Math	One Level Below College Math	Two Levels Below College Math	Three Levels Below College Math	Four Levels Below College Math	None or Vocational Math Only
3.00	5.14	4.55	5.14	4.92	4.77	4.91
4.00	5.84	5.01	5.40	5.10	5.06	5.18
5.00	6.46	5.44	5.69	5.34	5.38	5.45
6.00	7.03	5.86	6.01	5.62	5.73	5.73
7.00	7.55	6.25	6.34	5.94	6.10	6.02
8.00	8.04	6.64	6.69	6.28	6.49	6.31
9.00	8.51	7.02	7.05	6.64	6.89	6.60
10.00	8.96	7.39	7.42	7.01	7.30	6.89
11.00	9.38	7.75	7.80	7.41	7.71	7.18
12.00	9.79	8.10	8.19	7.81	8.14	7.48
13.00	10.19	8.45	8.58	8.23	8.57	7.78
14.00	10.57	8.80	8.98	8.65	9.01	8.08
15.00	10.94	9.14	9.38	9.09	9.45	8.38
16.00	11.30	9.47	9.79	9.53	9.90	8.68
17.00	11.66	9.81	10.20	9.98	10.35	8.98
18.00	12.00	10.13	10.61	10.44	10.81	9.28

Note: Assumes a student whose point of entry to remedial math was beginning algebra, whose highest-skill successfully-completed writing course was college composition, whose goal at college entry was upward transfer to a four-year institution in combination with an associate's degree, and who did not complete a credential prior to exiting remedial math.

Table 12: Results of the random-intercept logistic regression of successful course completion in the after-math period on selected variables ($N_{students}$ = 55,921; $N_{courses}$ = 510,338)

	Coefficient	Std Error
Point of Entry to Math		
2 levels below college (vs. 1 level below college)	0.00	0.02
3 levels below college (vs. 1 level below college)	0.03	0.02
4 levels below college (vs. 1 level below college)	-0.05	0.03
Point of Exit from Math		
1 level below college (vs. college-level)	-2.10***	0.36
2 levels below college (vs. college-level)	-2.28***	0.34
3 levels below college (vs. college-level)	-2.62***	0.35
4 levels below college (vs. college-level)	-2.79***	0.34
none or vocational only (vs. college-level)	-3.01***	0.32
Prior Course Success Rate		
identity	8.08***	0.48
identity * point of exit = 1 level below college	-2.76***	0.60
identity * point of exit = 2 levels below college	-2.65***	0.56
identity * point of exit = 3 levels below college	-4.25***	0.61
identity * point of exit = 4 levels below college	-4.65***	0.60
identity * point of exit = none or vocational only	-5.64***	0.51
square root	-7.72***	0.78
square root * point of exit = 1 level below college	4.21***	0.92
square root * point of exit = 2 levels below college	4.19***	0.87
square root * point of exit = 3 levels below college	5.46***	0.90
square root * point of exit = 4 levels below college	6.08***	0.88
square root * point of exit = none of vocational only	6.66***	0.80
Highest-Skill Writing Course Completed Prior to Exiting Math		
1 level below college (vs. college-level)	-0.21***	0.02
2 levels below college (vs. college-level)	-0.31***	0.03
3 levels below college (vs. college-level)	-0.34***	0.05
4 or 5 levels below college (vs. college-level)	-0.22*	0.11
none or vocational only (vs. college-level)	-0.12***	0.02
Academic Goal at College Entry		
transfer (vs. transfer + associate's degree)	0.01	0.03
academic associate's degree (vs. transfer + associate's degree)	0.17***	0.03
vocational associate's degree (vs. transfer + associate's degree)	0.20***	0.05
vocational certificate (vs. transfer + associate's degree)	0.31***	0.06
other job-related (vs. transfer + associate's degree)	0.25***	0.03
personal development (vs. transfer + associate's degree)	0.19***	0.03
remediation (vs. transfer + associate's degree)	0.14**	0.05
undecided (vs. transfer + associate's degree)	0.08***	0.02

	missing (vs. transfer + associate's degree)	0.16***	0.04
Completed Credential Prior to Exiting Math			
	yes (vs. no)	0.03	0.04
Constant		2.08***	0.32

$*p \leq 0.05;$ $**p \leq 0.01;$ $***p \leq 0.001$

Table 13: Predicted probability that any given course taken in the after-math period was completed successfully as a function of course success rate prior to exiting remedial math and point of exit from remedial math (based on the estimates provided in Table 14)

Prior Course Success Rate	Point of Exit from Math (Highest-Skill Math Course Completed Successfully)					
	College-Level Math	One Level Below College Math	Two Levels Below College Math	Three Levels Below College Math	Four Levels Below College Math	None or Vocational Math Only
0.10	0.62	0.36	0.32	0.30	0.29	0.26
0.15	0.58	0.36	0.32	0.30	0.30	0.27
0.20	0.57	0.37	0.33	0.31	0.32	0.28
0.25	0.56	0.39	0.35	0.33	0.34	0.30
0.30	0.57	0.42	0.38	0.35	0.36	0.31
0.35	0.59	0.44	0.40	0.37	0.38	0.33
0.40	0.61	0.47	0.44	0.39	0.41	0.35
0.45	0.63	0.51	0.47	0.42	0.43	0.37
0.50	0.66	0.54	0.51	0.44	0.46	0.39
0.55	0.69	0.58	0.54	0.47	0.49	0.41
0.60	0.72	0.61	0.58	0.50	0.52	0.43
0.65	0.75	0.65	0.62	0.53	0.55	0.45
0.70	0.78	0.68	0.66	0.56	0.58	0.47
0.75	0.81	0.72	0.69	0.59	0.61	0.49
0.80	0.84	0.75	0.73	0.62	0.64	0.52
0.85	0.86	0.78	0.76	0.65	0.67	0.54
0.90	0.88	0.81	0.79	0.68	0.69	0.56
0.95	0.90	0.83	0.82	0.71	0.72	0.59
1.00	0.92	0.86	0.85	0.74	0.75	0.61

Note: Assumes a student whose point of entry to remedial math was beginning algebra, whose highest-skill successfully-completed writing course was college composition, whose goal at college entry was upward transfer to a four-year institution in combination with an associate's degree, and who did not complete a credential prior to exiting remedial math.

Figure 1: Predicted probability that any given course taken in the after-math period was vocational as a function of proportion of vocational courses prior to exiting remedial math and point of exit from remedial math (from Table 9)
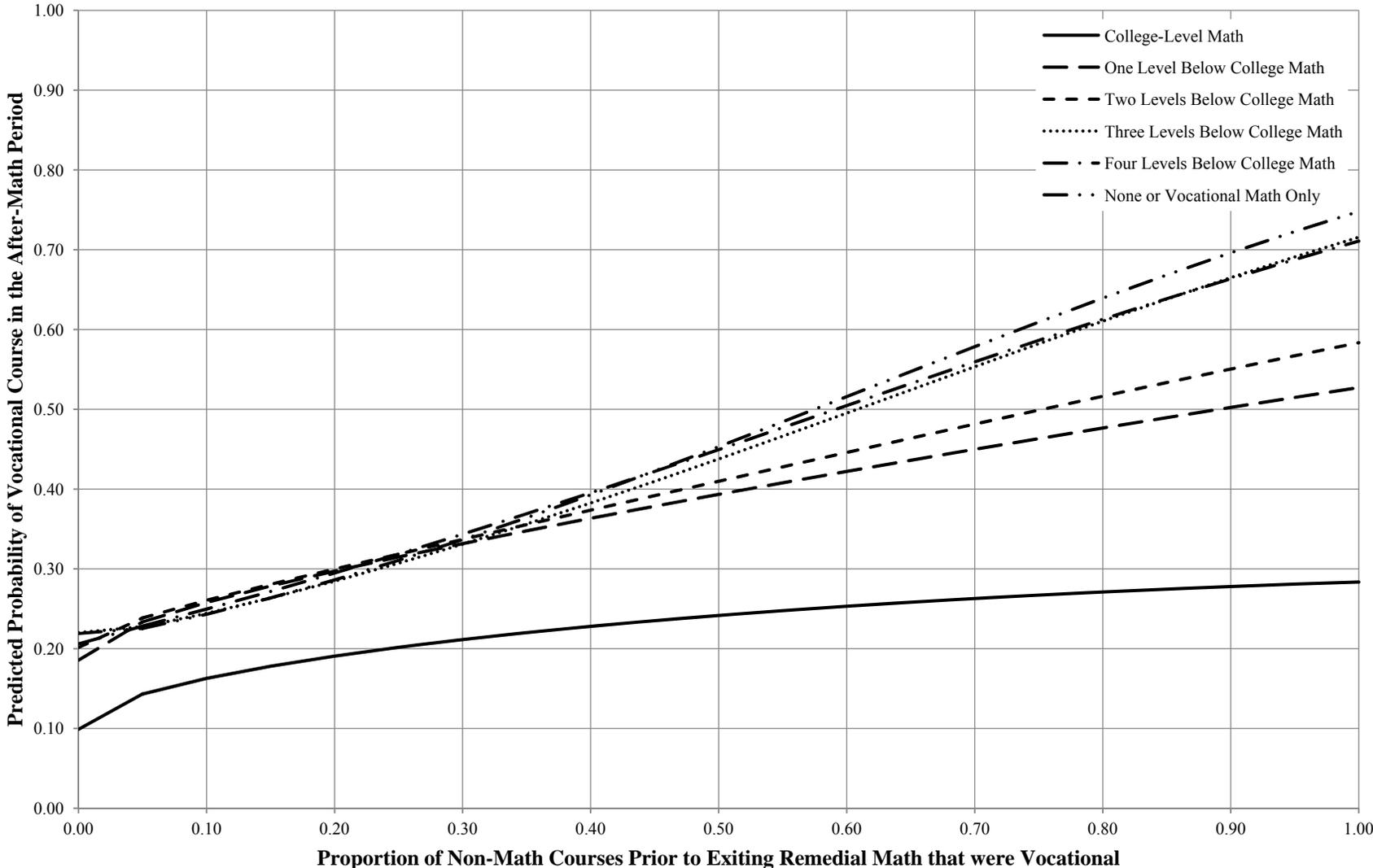
Figure 2: Predicted mean course credit load in the after-math period as a function of mean course credit load prior to exiting remedial math and point of exit from remedial math (from Table 11)
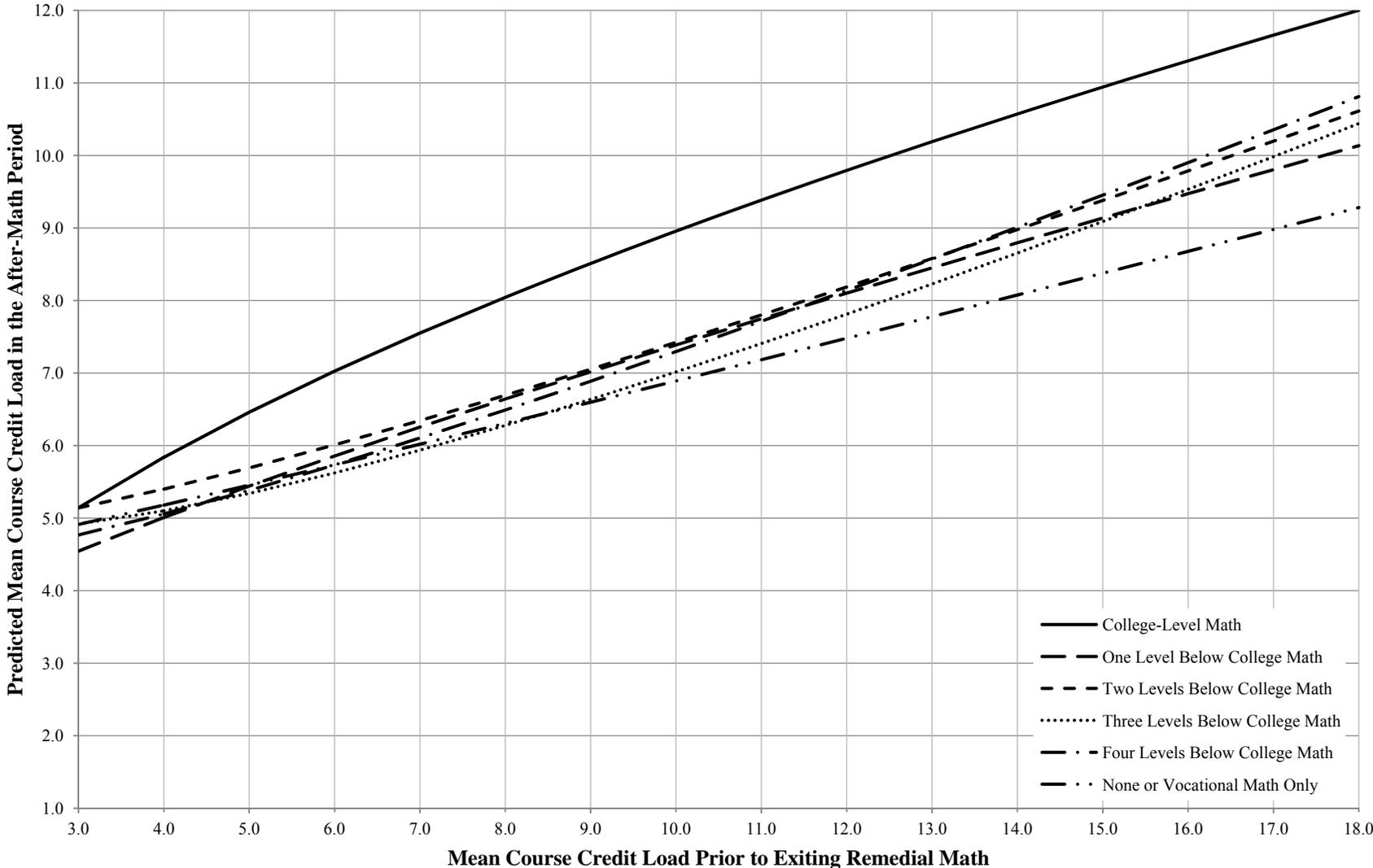
Figure 3: Predicted probability that any given course taken in the after-math period was completed successfully as a function of course success rate prior to exiting remedial math and point of exit from remedial math (from Table 13)