

2021

Course Design and Academic Outcomes in Quantitative Literacy After Eliminating Required Remediation

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Recommended Citation

Clinkenbeard, Jennifer E.. "Course Design and Academic Outcomes in Quantitative Literacy After Eliminating Required Remediation." *Numeracy* 14, Iss. 1 (2021): Article 3. DOI: <https://doi.org/10.5038/1936-4660.14.1.1373>

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Abstract

In Fall 2018, remedial mathematics courses were eliminated from the 23-campus California State University system under Executive Order 1110. Incoming first-year students were placed into college credit-bearing mathematics courses with options for corequisite support. This study examines the academic outcomes for students at California State University Monterey Bay in a college credit level quantitative literacy (QL) mathematics course with optional corequisite support during the 2018-2019 academic year. Taken together, the results of this study suggest that required remediation is not necessary for success in college-level QL. The corequisite support model also has potential to support more equitable outcomes for all students. However, further study is needed to identify institutional, departmental, and pedagogical best practices for effective corequisite support in QL.

Keywords

quantitative literacy, corequisite, access, equity, remediation

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Cover Page Footnote

Jennifer Elyse Clinkenbeard is an assistant professor of mathematics at California State University, Monterey Bay. She holds a PhD in Education from Claremont Graduate University (2017) and master's and bachelor's degrees in mathematics from California State University, Channel Islands (2011, 2009). She is interested in active learning in postsecondary mathematics and its potential for reducing equity gaps.

Introduction

In 2017, the California State University Office of the Chancellor released Executive Order 1110 stating that all incoming California State University (CSU) students would be placed directly into college credit-bearing mathematics courses by Fall 2018 (California State University 2017). Previously, CSU students were placed in up to two semesters (one academic year) of remedial mathematics, which did not count toward their degree. These courses focused on high school-level algebraic skills and techniques. The rationale was that the remediation would help underprepared students to be successful in their college credit-bearing math courses, which they would then take in the second or third semester of college.

However, there was a significant equity issue with this approach. Underrepresented minority students, first generation students, and low-income students were disproportionately placed into remedial math coursework compared to their non-underrepresented peers. According to the 2015 Complete College America executive report, 42% of incoming US college students were enrolled in remediation. However, only 35% of White students were enrolled in remediation, compared to 56% of African American students and 45% of Hispanic students. Similarly, 55% of students who received a Pell Grant were enrolled in remediation (Complete College America 2016).

The CSU reported similar trends for incoming freshmen (California State University, n.d.) In Fall 2015, 27.4% of incoming freshmen were designated as needing remediation in math. However, only 12.9% of White, non-Latino students were required to take remedial math, compared to 48.2% of African American students and 36.9% of Mexican American and other Latino students. In the CSU system, Mexican American and other Latino students were the largest ethnicity group, comprising 44% of the 64,399 incoming CSU freshmen. More than 10,000 Mexican American and other Latino students were required to take remedial math in 2015.

Remedial coursework increased time to graduation, and students who began in the remedial courses were ultimately much less likely to earn their bachelor's degree (Jaggars and Stacey 2014). Nationally, only 36% of students at four-year universities who began in remediation completed the associated introductory college course within two years (Complete College America 2016). Additionally, the affective component of being "conditionally admitted" to a university, based on performance on a single test (Entry Level Mathematics examination), contributed to a deficit mindset. A deficit mindset refers to focusing on students' shortcomings and problems rather than their potential. Deficit views of mathematics learning include both how students are labeled, often based on results from a standardized

test, as well as a restricted definition of mathematics and its role as a gatekeeper (NCSM/TODOS, 2016).

These concerns about educational equity and student retention resulted in Executive Order (EO) 1110. This policy change had major effects among faculty and programs across the state, including many discussions about what appropriate corequisite support would look like and if it would be enough for students to be successful in the college level course.

This paper examines the corequisite support model implemented at California State University Monterey Bay (CSUMB) and academic outcomes for students in a college credit-level quantitative literacy (QL) mathematics course titled MATH 100: Quantitative Literacy. The corequisite model in this study is comprised of an optional support course, taken in the same semester as MATH 100, emphasizing course-level material together with building mathematical and study skills. We consider students who had successfully completed remediation prior to the QL course, as well as students who started directly in the QL course after EO 1110.

Models and Research Questions

Before EO 1110, incoming first-year students were placed either into remedial mathematics coursework or college credit-bearing coursework. Students who scored below a threshold on the Entry Level Mathematics exam (ELM) were placed into one or two semesters of remediation, creating two groups of students in college credit-bearing coursework: students who began in those courses and students who had successfully completed their required remedial algebra sequence. This structure is shown below in Figure 1.



Figure 1. Placement prior to EO 1110.

With EO 1110 and the elimination of the remedial algebra sequence, campuses were given a choice for how to implement appropriate support for incoming first-year students in college credit-bearing courses. CSUMB created corequisite courses to accompany each first-year math course. The courses are two-hour, once per week, lab-like courses paired to each general education math course, taught by faculty who were also teaching the first-year course. Students self-selected into these corequisite support courses following a directed self-placement recommendation and/or a recommendation based on multiple-measures placement. The courses were open to all students, including those who had previously completed remediation under the old curricular structure.

Therefore, each of the groups shown in blue and green in Figure 1 became two groups. In Figure 2, both groups in blue did not have to complete required remediation. Students who matriculated pre-EO 1110 and were designated college ready, or any student who matriculated in Fall 2018 or later, fell into this category. Beginning in Fall 2018, students could choose to take their introductory college level mathematics course together with corequisite support. In Figure 2, both groups in green were students who had matriculated pre-EO 1110 and successfully completed required remediation prior to Fall 2018. Again, the students could choose to take the introductory college-level mathematics course with or without support. This created the four groups in Figure 2, which we refer to throughout this paper.

Group 1: No Remediation Required, Opted Out of Support Course	Group 2: Remediation Required, Opted Out of Support Course
Group 3: No Remediation Required, Opted into Support Course	Group 4: Remediation Required, Opted Into Support Course

Figure 2. Placement upon implementation of EO 1110.

This paper focuses on students who took MATH 100: Quantitative Literacy, a college credit-bearing course at CSUMB, in the 2018–2019 academic year. Because this was the first year of implementation of EO 1110, the model in Figure 2 represents the students in the study. We investigate the following research questions:

RQ1: How did students' academic achievement in the QL course vary by prior remediation and corequisite support?

RQ2: How did students' academic achievement in the QL course vary by demographic characteristics?

RQ3: What were the best predictors for students' academic achievement in the QL course?

National Findings from Corequisite Mathematics Implementation

Several large university and community college systems have implemented corequisite models with promising results. In 2015, Tennessee's Community College system implemented corequisite remediation in math, writing, and reading at all of its 13 campuses. The results showed that under the old model, fewer than 10% of students completed a credit-bearing math class in a single semester; with the corequisite model at scale, more than 70% of students did so (Tennessee Board

of Regents 2016). The Community and Technical College System of West Virginia and Ivy Tech Community College in Indiana also reported more than 60% of students completing a college credit-bearing mathematics course in one semester after implementing corequisite remediation (Complete College America 2016).

“Pathway” courses are also becoming more popular. These are typically courses with embedded remediation and support with content that is tailored to the students’ chosen field of study. The Colorado Community College system was one of the early large-scale adopters of this model. Sixty-four percent of students in a pathway model completed their first-year math or statistics course within one year, compared with a 31% completion rate in two years for students who began in remediation (Complete College America 2016). In 2015–2016, the Carnegie Foundation “Statway” and “Quantway” courses had been implemented across 56 institutions in 14 states and reported successful course completion rates of 55% (Hoang et al. 2017).

While these results are promising, they report on the completion rates of all introductory courses, which include college algebra, precalculus, statistics, and other STEM-based courses together with quantitative literacy courses. Given the difference in context for QL courses, it is necessary to disaggregate this group of students to examine relevant student outcomes under remedial and corequisite structures. Matz and Tunstall (2019) published a pilot study which included two QL courses at Michigan State University. The pilot included embedded support in an additional weekly class meeting, termed “enhanced” courses. The researchers found that students who had successfully completed a remedial course prior to taking enhanced QL earned significantly lower course grades than those who would have been required to take remediation, but instead participated in the enhanced QL course without additional remediation. The researchers conjectured that embedded remediation did not necessarily result in equitable outcomes for students given that students with additional prior remediation did not do as well as those without it (Matz and Tunstall 2019).

Our study is unique because the corequisite structure at CSUMB meant that incoming first-year students had the option to take QL with or without corequisite support. Returning students who had completed their remediation requirement or tested out of it had these same options. Students who chose to take corequisite support were also in the same QL class with students who did not. This approach is called *co-mingling*, which refers to courses that mix college-ready and underprepared students who are taking corequisite support into the same college-level class (Hartzler and Blair 2019). By investigating academic outcomes for QL students in the first year of implementation, as well as disaggregating outcomes by support, prior remediation, and demographic characteristics, we can better understand how well corequisite mathematics serves all students.

QL Corequisite Mathematics Implementation at CSUMB

Because this study is specific to QL students at CSUMB, we briefly discuss the context for the course. The content for the QL course in this study is consistent with the recommendations from the Mathematical Association of America's recommendation for current practices (Gillman 2006). CSUMB's QL course is structured around numeracy, some algebraic and geometric skills, and probability and statistics. The coursework also emphasizes development of QL "habits of mind" from Association of American Colleges and University's VALUE rubric, including interpretation, representation, calculation, application, assumptions, and communication (Association of American Colleges and Universities 2009).

QL Course Design & Pedagogy

The QL course was also redesigned with Reading Apprenticeship and Complex Instruction pedagogies. The purpose of doing so was to create more equitable opportunities for participation and engagement in the QL course. Reading Apprenticeship is a pedagogical framework designed to apprentice students as readers in a specific discipline (Schoenbach, Greenleaf, and Murphy 2012). The framework attends to four dimensions: social, personal, cognitive, and knowledge-building. This is focused around the metacognitive conversation, both internally as students individually read and consider their own mental processes, and externally as they talk about their strategies, resources, motivations, and affective responses to texts (Schoenbach et al. 2012). This framework challenges the deficit mindset that students are unmotivated, passive, and give up easily when it comes to understanding through reading. Complex instruction is a pedagogy initially designed for K–12 students. It focuses on groupwork, defined as "students working together in a group small enough so that everyone can participate on a clearly assigned learning task" (Cohen and Lotan 1997, 2). This groupwork has three defining characteristics: group-worthy tasks supporting multiple abilities; autonomy of the group through norms and roles; and attending to status through individual and group accountability (Cohen and Lotan 1997). This promotes equitable participation by all members in a group. Both of these pedagogical frameworks were adapted for the QL course context and implemented with the new corequisite structure.

Two groups of students typically take the QL course. It is required for liberal studies majors who have a goal of becoming an elementary school teacher. These students are also then required to take two upper-division elementary mathematics methods courses to earn their undergraduate degree. It is also often taken by

students whose chosen majors do not require mathematics beyond a one-semester general education requirement, such as arts or humanities.

Remedial Algebra Structure & Placement

Prior to the introduction of EO 1110, CSUMB offered a two-semester remedial algebra sequence. This program had won awards for innovative design and pedagogy, using large-format class sections and active learning with peer mentors in a 90-seat computer lab. This design was implemented in conjunction with intensive summer programs for incoming students who were designated as not college ready. In 2015, 582 students took one or both remedial mathematics courses, with an overall course success rate of 88%. Remedial mathematics at CSUMB was widely considered a successful program prior to EO 1110.

Placement was determined using the Entry Level Math (ELM) test. This placement test was used CSU-wide and required for all incoming first-year students who had not met opt-out criteria with a high SAT or ACT math score. Based on a student's ELM score, they were required to take one or two semesters of remedial algebra, as well as possible summer school prior to their freshman year. The same remedial algebra courses were required for all students who placed into them, regardless of major or chosen field of study. In order to continue at the university, students needed to complete their remediation requirement within one year of matriculation.

Corequisite Structure & Placement

When the remedial algebra courses were eliminated, CSUMB created corequisite courses to accompany each first-year math course. The two-hour, once per week, lab-like courses are paired to each general education math course. They are taught by faculty who are also teaching the first-year course. Students self-selected into these corequisite support courses following a directed self-placement recommendation and/or a recommendation based on multiple-measures placement. The courses were open to all students, including those who had previously completed remediation under the old curricular structure. However, students were given the choice to take the QL course with or without the corequisite course.

The corequisite course for the quantitative literacy course included three components: review of mathematical skills and concepts related to those needed for current course material; student success strategies; and extra practice on course material. A typical class session included a content activity aligned to course material; a short student success discussion or task; and time to work with an adaptive online math software to build relevant skills.

The multiple-measures placement, determined by the CSU system, categorizes students as follows: Category I—General Education Math completed; Category II—Ready for General Education Math; Category III—Recommended for Support;

Category IV—Support Required. Although students who were designated as Category IV were strongly recommended by an advisor to enroll in support, not all students in Category IV actually took the support course. Multiple-measures placement variables included high school GPA, SAT or ACT math score, the student's chosen field of study, and math classes taken in high school.

The directed self-placement tool was developed by faculty at CSUMB, including first-year writing faculty who had previously developed a similar tool. Adapting the findings from best practices in writing, CSUMB faculty developed a tool that consists of an introductory video, questions regarding students' major choice, and a set of multiple choice and open-ended math problems. The student then completes a survey to reflect on their performance, experiences, and expectations in college level mathematics. The recommendation is generated based on the student's choice of major and their response to the survey questions.

Both multiple-measures placement and directed self-placement were used for the first time at CSUMB for mathematics placement in the summer before the study. All incoming students received a multiple-measures placement recommendation. About 35% of incoming QL students completed the directed self-placement activity. Although the focus for this study is not on the efficacy of placement structures and methods, they are important to consider in the larger context of the structural changes associated with eliminating the ELM and remedial mathematics requirement.

Methods

The subjects for this study were all CSUMB students enrolled in the QL course during the 2018–2019 academic year. All QL course sections and corequisites during this academic year were taught in a face-to-face modality. The study was designated exempt from the university's IRB office, meaning that there was no risk to participants beyond those associated with daily life. Data were obtained from the university's office of institutional research. It should be noted that the author of this paper is the course coordinator, and one of three instructors, for the QL course during this time. However, because redacting her students from these analyses would result in a significantly reduced sample size, all students in the QL course during this year are included in the following analyses. Table 1 below indicates enrollment and demographic information for CSUMB and for the subjects for the study in the academic year 2018–2019. Underrepresented minority (URM) race or ethnicity includes students of Latinx, African American, Native American, and Pacific Islander races or ethnicities.

Table 1
University and QL Course Demographics

	Enrollment	Gender	Race or ethnicity		Pell eligible	First-generation
CSUMB	7,545 students	Female 63%	Latinx	42%	33%	51%
			Other URM*	7%		
	20% first-time first-year	Male 37%	White	29%		
QL Course	142 students	Female 74%	Other non-URM**	23%	55%	51%
			Latinx	58%		
			Other URM*	7%		
	66% first-time first-year	Male 26%	White	20%		
			Other non-URM**	15%		

*Includes African American, Native American, Pacific Islander

**Includes Asian American, Other/Decline, Two or More Races

Subjects for the Study

There were four groups of students in this study as per Figure 2. Table 2 below indicates the sample size for each group in the study.

Table 2
Four Groups of Students by Remediation and Corequisite Support

Group 1	QL Course only $n = 75$
Group 2	Remediation Completed + QL Course $n = 35$
Group 3	Support + QL Course $n = 22$
Group 4	Support + Remediation Completed + QL Course $n = 10$

Group 1 is comprised of students who took the QL course without support ($n = 75$). These students may have been recommended as college-ready or recommended for support but chose to take the course without it. Group 2 is

comprised of students who took the QL course after previously successfully completing remediation ($n = 35$). These students include second-year or later students who began at CSUMB under the old curricular structure, required at least one semester of remediation, and successfully completed it. Group 3 is comprised of students who took the QL course with support and had not previously had remediation ($n = 22$). This group consists entirely of first-time first-year students who began at CSUMB after remediation was eliminated. Group 4 is comprised of students who successfully completed remediation under the old curricular structure and chose to take the QL class with support ($n = 10$). All four of these groups took the redesigned QL course in Fall 2018 or Spring 2019, with the option of taking the support course available.

Results

We restate the research questions:

RQ1: How did students' academic achievement in the QL course vary by prior remediation and corequisite support?

RQ2: How did students' academic achievement in the QL course vary by demographic characteristics?

RQ3: What were the best predictors for students' academic achievement in the QL course?

RQ1: Academic Achievement by Prior Remediation and Corequisite Support

We consider course pass rate and course GPA as measures of academic achievement. Passing grades are defined as a semester course grade of C- or higher. Course GPA is calculated using "A" through "F" grades on a standard 4-point scale, with "W" grades redacted from analyses.

All QL students from AY 2018–2019 ($n = 142$) were included in the following analyses. The overall course pass rate was 89.4%. The average course GPA was 2.91, with a standard deviation of 1.05. Table 3 below includes the course pass rate, average course GPA (denoted \bar{x}) and standard deviation (s.d.) of course GPA by each of the four groups.

Table 3
Course Pass Rates and Average Course GPA by Remediation and Corequisite Support

Group 1	QL Course only ($n = 75$) Course pass rate: 93.3% Course GPA: $\bar{x} = 3.19$, $s.d. = 0.95$
Group 2	Rem. + QL Course ($n = 35$) Course pass rate: 91.4% Course GPA: $\bar{x} = 2.69$, $s.d. = 0.92$
Group 3	Support + QL Course ($n = 22$) Course pass rate: 77.2% Course GPA: $\bar{x} = 2.60$, $s.d. = 1.26$
Group 4	Support + Rem. + QL ($n = 10$) Course pass rate: 80.0% Course GPA: $\bar{x} = 2.27$, $s.d. = 1.24$

The largest student group was Group 1: QL course only, 68% of whom were first-time first-year students. The elimination of the Entry Level Mathematics placement exam makes it difficult to determine how many of these first-year students would have been placed in remedial coursework under the old curricular structure. However, historically 50% of QL students at CSUMB had previously completed remediation. It is highly

likely that some incoming students would have been required to take at least one semester of remediation under the previous policy. This group had both the highest course pass rate (93.3%) and average course GPA (3.19).

Students in Group 2: QL + Remediation had a similar course pass rate to students in Group 1. Because students in Group 2 had completed prior required remediation, they were not first-time first-year students. The average course GPA for Group 2 was 0.5 grade points lower than Group 1.

Group 3: QL + Support and Group 4: QL + Remediation + Support were the smallest groups, with 22 and 10 students, respectively. An important covariate to consider for Groups 3 and 4 was their success in the support course. Twenty-four of the 32 students in Groups 3 and 4 (75%) earned passing grades in both the support course and the QL course. The course pass rates for students in Groups 3 and 4 were similar. However, the average course GPA for students in Group 4 was 0.33 grade points lower compared to students in Group 3.

Although differences were observed in student grades and pass rates in each of the four groups, it is possible that some of these differences could be attributed to random chance, especially given the sample size of some of the groups. To determine significant differences between groups, two analyses were performed: a Kruskal-Wallis test to compare pass rates, and a one-way ANOVA to compare letter grades. The results of the Kruskal-Wallis test shows that the distribution of pass rates was the same across all four groups of students ($p = 0.127$), indicating no significant difference in pass rate among the four groups.

In the one-way ANOVA, letter grades were coded on a standard 4-point scale. Although the sample sizes were not equal for the four groups, the test for homogeneity of variances indicated no significant difference in variances between groups (Levine statistic 1.667, $p = 0.177$), indicating the ANOVA is appropriate for this analysis. The results of the ANOVA are given in Table 4 below.

Table 4
Results of ANOVA

	Sum of squares	df	Mean square	<i>F</i>	Sig.
Between groups	13.508	3	4.503		
Within groups	142.187	137	1.038	4.339	0.006*
Total	155.695	140			

*statistically significant difference at $p < 0.05$

A Tukey Honestly Significant Difference (HSD) post hoc comparison was conducted to identify significant differences between the four groups. The results of the post hoc analysis are given in Table 5 below. Each cell indicates the mean difference in course GPA between those two groups. Statistically significant differences are marked with *.

Table 5
Results of Tukey HSD Post Hoc Comparison

	Group 1	Group 2	Group 3	Group 4
Group 1	1	0.4994	0.5806	0.9151*
Group 2		1	0.0812	0.4157
Group 3			1	0.3346
Group 4				1

*statistically significant difference at $p < 0.05$

There was a significant difference in course grade at the $p < 0.05$ level for the four groups of students ($F_{3, 137} = 4.339$, $p = 0.006$, $\eta^2 = 0.0868$). The effect size of

0.0868 is low, indicating a small meaningful difference between the four groups. This may also be due in part to the unequal sample size of the groups (Kirk 1996).

Post hoc comparisons using the Tukey HSD test indicated that the mean score for students in Group 1 (no support and no remediation) was significantly different than students in Group 4 (support and remediation) ($p = 0.042$). However, there were no significant differences in course grade between any other groups.

RQ2: Academic Outcomes by Demographic Characteristics

As in the first research question, course pass rates and average course GPA are used as measurable academic outcomes. Figure 3 presents course pass rates for QL students on the following variables: Underrepresented minority (URM) race or ethnicity, first generation, Pell Grant eligibility, and gender. Underrepresented race or ethnicity is defined as in Table 1, including students of Latinx, African American, Native American, and Pacific Islander races or ethnicities. Because of the small number of non-Latinx URM students in the study ($n = 10$), academic outcomes for URM students are not further disaggregated by race or ethnicity to ensure anonymity. The institutional data coded gender for all 142 students as binary “male” or “female.” No information about nonbinary gender was available.

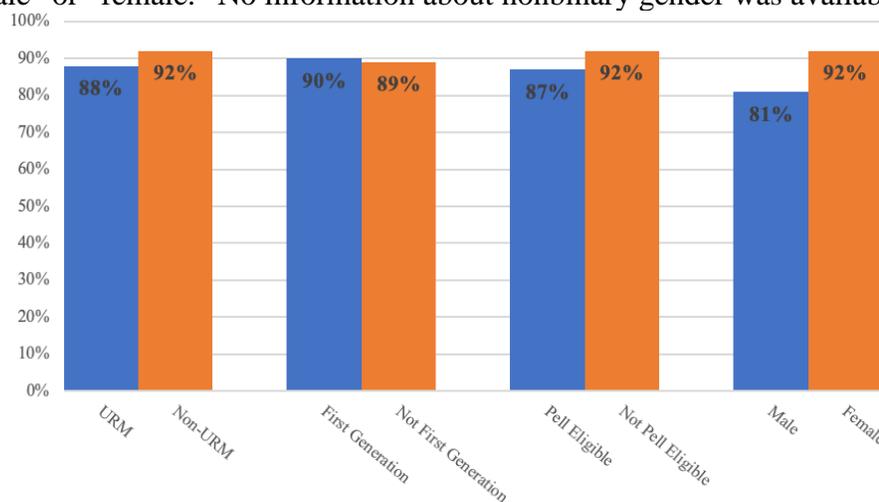


Figure 3. Course pass rate by URM race or ethnicity, first generation, Pell eligibility, and gender.

Using a percentage point gap method, the pass rate in Figure 3 for each disaggregated subgroup of students was compared with the overall pass rate of the course (89%). Using this approach, the -8 percentage point gap for male students (81% pass rate for male students compared to 89% overall pass rate) suggests evidence of an equity gap by male gender (Center for Urban Education 2018). No other disaggregated subgroups, including URM, first generation, Pell eligible, and prior remediation showed a negative equity gap of three points or larger in these data using this approach.

A two-tailed t -test for comparison of means was also conducted on each of the variables presented in Table 6 on the outcome of average course GPA. To minimize Type 1 errors, we ensure that the ratio of at least 30:1 data points per test is observed.

Table 6
Course GPA by URM, First-generation Status, Pell Eligibility, and Gender

	<i>n</i>	Avg. Course GPA	Std. dev.	<i>t</i> -statistic	<i>p</i> -value
URM	93	2.81	1.07	$t = 1.511$	$p = 0.133$
Non-URM	48	3.09	1.00		
First-gen.	72	2.90	1.07	$t = -0.065$	$p = 0.948$
Not First-gen.	69	2.91	1.05		
Pell Elg.	77	2.75	1.12	$t = 1.900$	$p = 0.059$
Not Pell Elg.	64	3.09	0.95		
Male	37	2.74	1.12	$t = -1.110$	$p = 0.269$
Female	104	2.96	1.03		

*statistically significant difference at $p < 0.05$

The results of Table 6 indicate that there were no statistically significant differences in course GPA by gender, URM status, Pell eligibility, and first-generation status. Although not statistically significant, there were observed differences in course GPA by URM status (-0.28), Pell eligibility (-0.34), and male gender (-0.22). Because the differences were not statistically significant, it is possible they were due to random chance. Given the context of historical equity gaps in mathematics outcomes on these variables, it is important to include the result that there are no significant differences on these variables in the sample.

RQ3: Best Predictors for Academic Outcomes

Regression analyses are presented to account for potential overlap in the variables considered in the study, as well as to consider some additional measures. The independent variables are gender, URM status, first generation status, Pell eligibility, remediation, support course, CSU multiple-measures placement category, high school GPA, and academic level. A stepwise linear regression is presented with the dependent variable of course grade. A binary logistic regression is presented with the dependent variable of pass/fail. Missing data were handled by pairwise deletion, and the stepwise procedure was done at a 0.05 significance level. A summary of the variables, variable types, possible values, and sample size is included below in Table 7.

Table 7
Variables Considered in Regression Analysis

Variable	Data type	<i>n</i>
Gender	Dichotomous	142
URM status	Dichotomous	142
First generation status	Dichotomous	142
Pell eligibility	Dichotomous	142
Number of remedial courses, including summer programs	Ordinal	142
Enrolled in corequisite support course	Dichotomous	142
CSU multiple-measures placement	Ordinal	106
High school GPA	Interval	132
Academic level (freshman, sophomore, junior, senior)	Ordinal	142

Although there were missing data for some students on the variables of CSU multiple-measures placement and high school GPA, they have been included in the regression with pairwise deletion of missing data. This resulted in a listwise valid *n* of 97 for both analyses. The variables of SAT math score, ACT math score, directed self-placement recommendation, and prior university GPA all had missing data for more than 50% of participants and were thus not included.

We predicted course grade in the QL course, coded on a standard 4-point scale. Of the nine variables considered, only one entered the regression, namely, high school GPA. The R^2 was 0.130, meaning that 13.0% of the variation in course grade could be accounted for by this variable. Thus, only high school GPA was a positive predictor with a standardized beta of 0.361. The results of the regression are presented in Table 8 below. The regression analysis indicates that of the set of variables considered, only high school GPA has significant predictive power when it comes to QL course grade.

Table 8
Results of the Linear Regression Analysis

Variable	Beta Standardized		<i>t</i>	<i>p</i>
High school GPA	0.361		3.774	< 0.001
<i>n</i> = 97	<i>R</i> = 0.361	<i>R</i> ² = 0.130	<i>F</i> = 14.245	<i>sig.</i> <i>F</i> < 0.001

We then predicted pass or fail grades using binary logistic regression. Grades of C- or higher were passing grades and grades of D+ or lower were failing grades. The same set of input variables were considered. Again, missing data were handled by pairwise deletion. Of the variables considered, none were statistically significant at or below the 0.05 level. The classification model before and after the regression is presented below in Table 9.

The model with all nine variables accurately predicted if a student passed or failed 88.7% of the time, which is the same as the baseline model with no predictor variables. This indicates the set of variables in the model does not predict pass or fail grades in QL for this sample.

Table 9
Classification Before and After Binary Logistic Regression

	Observed		Predicted		Percentage Correct
			Pass or Fail		
			Fail	Pass	
Step 0	Pass or Fail	Fail	0	11	0
		Pass	0	86	100
	Overall Percentage				88.7
Step 1	Pass or Fail	Fail	1	10	9.1
		Pass	1	85	98.8
	Overall Percentage				88.7
Nagelkerke's $R^2 = 0.245$			-2LL = 55.724	Constant = -1.243	

Discussion

The first research question focused on academic achievement by remediation and/or corequisite support. Four groups were defined: Group 1, comprised of students who took the QL course without support ($n = 75$); Group 2, comprised of students who took the QL course after previously successfully completing remediation ($n = 35$); Group 3, comprised of students who took the QL course with support and had not previously had remediation ($n = 22$); Group 4, comprised of students who successfully completed remediation under the old curricular structure and chose to take the QL class with support ($n = 10$). There were no significant differences in pass rate among the four groups of students. However, Group 1 earned significantly higher course grades than Group 4. There were no other significant differences between groups on course grade. This means that there were no significant differences between Groups 1 and 2, who both took the QL course without support, even though Group 2 had previously completed remediation. Similarly, there were no significant differences between Groups 3 and 4, who both took the QL class with support, but Group 4 had previously completed required remediation. This indicates that students who took the support course had similar outcomes regardless of whether they had completed remediation prior to doing so, and that the same was true of students who did not take the support course. This suggests that completing remediation had little, if any, value added for QL students. This is consistent with Campbell and Cintron (2018), who found that students who would have otherwise placed in remedial mathematics, but who instead took a corequisite pilot course, achieved credit in college level math similar to students who had successfully completed remediation and then took the same college credit-bearing course (Campbell and Cintron 2018).

The significant difference in course grade between Groups 1 and 4 is potential cause for concern. However, the significant difference in course grade for these two very different groups of students may be at least partially explained by high school GPA, as discussed in the third research question. Further variation is likely due to other factors that were not measured in the study and could be better addressed

through qualitative data, such as student interviews about their lived experiences prior to taking the QL course.

It is important to consider the change in placement structures at the time of this study. Students who had completed prior remediation were required to do so, while students who took the support course elected to do so. Because the placement structures were not the same for all students in the study, there was no control group. Additionally, because taking the support course was elective and remediation was not, these should not be treated as similar indicators of college readiness. The presence of a student in a remedial course indicated a test score below a given cutoff value on the Entry Level Mathematics exam. The presence of a student in a support course indicated that the student chose to take it, perhaps (but not necessarily) on the basis of a multiple-measures recommendation or directed self-placement recommendation.

Although these analyses were focused on course pass rates and course GPA, a related consideration is important to the discussion: time to successful completion of a college credit-bearing math course. Students in Groups 2 and 4 (remediation completed) who were successful in the QL course still had a minimum of two to three semesters to get there, depending on their initial remediation placement. Students in Groups 1 and 3 (no remediation required) who were successful in the QL course had the opportunity to do so in a single semester. Given the well-documented observation that long remedial mathematics sequences decrease students' likelihood of college completion, the 89% pass rate of students who completed the QL course in one semester, without prior remediation, is promising (Complete College America 2016).

The second research question focused on equity gaps in the QL course. We investigated course pass rate and GPA by the disaggregated subgroups of gender, underrepresented minority race/ethnicity, Pell eligibility, and first-generation status. There was evidence of a possible equity gap on the variable of course pass rate by percentage point gap method disfavoring male students. However, there were no statistically significant differences by gender, URM race/ethnicity, Pell eligibility, or first-generation status. This suggests that the course design with active learning pedagogies, together with curricular placement changes, has resulted in more equitable academic outcomes for students in QL.

The third research question focused on determining the most important variables for predicting course grade and pass rates in QL. Of the variables considered, only high school GPA emerged as a predictor for course grade. Given that none of the variables of remediation, corequisite support, and multiple-measures placement entered the regression, this suggests that the differences in outcomes for students who had not been required to complete remediation and/or opted not to take the support course may have been linked to pre-college preparation. This is consistent with the findings of Kurlaender and Cohen (2019),

who found that high school GPA eclipsed both SAT scores and Smarter Balanced assessment scores when predicting first-year college GPA and second-year persistence. However, this should not be taken to indicate that high school GPA is the only predictor for academic outcomes in quantitative literacy. In the stepwise linear regression, 87% of variation in course grade was unaccounted for by the set of variables considered. In the binary logistic regression using the same set of variables, none of the variables were statistically significant and the model had no predictive power. This indicates that further study is needed to identify how to better support all students' success in QL.

Limitations

We recognize several limitations of this study. First, we were cognizant of the sample size when conducting quantitative analyses. There were fewer than 150 students in total and a high level of variation in prior mathematics experiences and demographic characteristics. In addition, the sample size for the different groups of students was uneven. This limited the statistical analyses that could be conducted, as well as the reliability of the results. Second, the study was done at a single institution. Although this helps to minimize variation due to institutional factors including placement structures and course design, it limits the generalizability of the results to other institutional contexts. Finally, the subjects for the study consisted specifically of students in quantitative literacy. Quantitative literacy courses are different in content than most statistics or calculus pathway courses. In particular, they are typically less algebra-intensive than most other mathematics general education coursework. Because QL is unique compared to other general education courses, it is important to study the implications of eliminating remediation for QL students. However, this also means that the outcomes observed for QL students may not be consistent with those in other general education course contexts.

There may also be a relationship between course outcomes and if a student followed his or her recommendation(s) for taking a support course. However, only about 35% of QL students completed the directed self-placement tool. About half of the 39 students who were recommended for support by multiple-measures placement actually took the support course. These data are insufficient to address this question at this time. The researchers for the study are continuing to collect these data over time, across all first-year mathematics and statistics courses at CSUMB.

This study is also limited because of its focus on access and achievement. The study does not address the critical axis of identity and power, which are necessary for a more complete understanding of equity (Gutiérrez 2009). Researchers at the institution have collected additional questionnaire and focus group data. As more

data are collected over time, the researchers plan to collect data to analyze questions related to power and identity in the redesigned QL course.

Conclusion

The elimination of required remediation from the entire California State University system with a one-year timeline resulted in a situation where all incoming mathematics students had the opportunity to take GE level courses alongside students who had previously been deemed “college ready” or had successfully completed remediation. Within the Quantitative Literacy context, students could feasibly complete their college mathematics requirement in one semester rather than needing two or three.

In the first year of implementation of corequisite support for QL course at CSUMB, the results of this study showed 89% of students passed the QL course. There was a difference in course pass rate for students who did, and did not, choose to take a corequisite support course. Students who did not take the corequisite support course passed QL at a higher rate than those who took it. However, there was no significant difference in each of these groups between students who had previously completed remediation and those who had not. This suggests little, if any, value added from required remediation prior to QL. Moreover, there were no significant differences when considering course GPA for all QL students by gender, Pell eligibility, first-generation status, and URM/non-URM ethnicities. This finding suggests that these outcomes are consistent for students across different demographic backgrounds.

The findings here suggest that remediation is not an effective way to help prepare students for their quantitative literacy course. Indeed, our evidence confirms that mandatory remedial courses can not only impede students’ abilities to complete their QL requirement but may disproportionately impact students from historically disadvantaged groups. Our evidence also indicates that while corequisite support courses may have the potential to improve academic outcomes for students, further study is needed to determine common characteristics of successful corequisite support models. Educational practitioners need to think carefully about the goals and outcomes of such courses and track both students’ progress and experiences, as well as institutional factors such as placement, scheduling, and advising.

As institutions and systems of higher education introduce corequisite support to replace remedial mathematics programs, we have (for a relatively short period of time) students who matriculated under the old set of rules in the same classes as those incoming under new ones. However, as in the case of the CSU, over time the four groups in first-year mathematics courses will collapse again to two: students

in corequisite support and students not in corequisite support. No students will have completed required remediation in the CSU. This is shown in Figure 4 below.



Figure 4. Long-term implementation of EO 1110.

Further study is needed over time and at multiple institutions with different corequisite implementations. There is still much that is unknown about the implications of eliminating required remediation at a systemwide level. Adding to our knowledge base while addressing limitations when possible, and acknowledging them when not, can

help practitioners who are faced with difficult decisions about systemic curricular change. The results of this study suggest that required remediation is not necessary for success in college-level QL. While there is still improvement needed, course redesign and structural changes may better support students for success in college-level mathematics.

Acknowledgment

The author acknowledges the valuable contributions of these colleagues at CSUMB: Drs. J. Canner, S. Kim, A. Lynch, P. Shereen, A. Unfried, and J. Wand for design, implementation, and ongoing evaluation of corequisite general education mathematics and statistics courses including the course in this study, as well as all those who supported the efforts to improve undergraduate mathematics and statistics instruction through course redesign with corequisite support. The author would also like to thank the editor and reviewers of the journal for their insights and suggestions on this paper.

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