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Math Course for Liberal Arts Majors: A Pilot with Embedded Remediation

Abstract
This study was designed to determine if embedded remediation is significant in accelerating the pathway to completion of a college-level math course for students needing remediation. The project studied the impact on student success in a quantitative literacy course at a Massachusetts four-year state university with remedial material embedded. The course satisfies the university's general education math requirement for students with liberal arts majors who are not required to complete college algebra or calculus-based courses. The paper begins with a presentation of the issues with remedial mathematics and its impact on students' graduation and persistence. Next, the paper covers the design and implementation of the pilot program. In addition, the placement criteria and the pilot nature of the program are discussed, including attempts at the random assignment of students to regular or embedded-remediation course groups. A discussion of the findings follows including that students succeeded in the course with embedded remediation at 87% compared to 72% for those in the traditional version of the course though the differences are not statistically significant at the sample size. The paper concludes with lessons learned and next steps at this university for further study.

Keywords
math, quantitative reasoning, remedial math, pilot

Cover Page Footnote
Eileen B. Perez, EdD is an assistant Professor in the Mathematics Department at Worcester State University. She is the founding director of the University's Math Center and has served as the Developmental Math Program Director since 2010. Eileen works on both developmental math and college access and has presented on both topics at national conferences. She is a co-developer and instructor of the liberal arts math course under study.

Hansun To, PhD is a Professor in the Mathematics Department at Worcester State University. Her main research areas include liberal arts math course, Inquiry Based Learning, undergraduate research study and applied math in particular composite materials. Hansun has published in the *Journal of Mathematical Analysis and Applications* and *Proceedings of SPIE,* and she has numerous publications, many with student co-authors, in the *College Math Journal*, *Math Magazine* and the *American Math Monthly*. Since 2012 she has served as the liberal arts math course coordinator and is a co-developer and instructor of the course under study.

Mary Fowler, PhD is a professor in the Mathematics Department at Worcester State University. At the time of this study, she was serving as chair of the Mathematics Department and also as instructor for one of the sections. She holds a PhD from Carnegie Mellon University in Statistics and works in the field of college access. Additionally, she serves as an expert witness as an applied statistician in legal cases.

Linda S. Larrivee, PhD is the Dean of the School of Education, Health, and Natural Sciences at Worcester

State University where she oversees ten academic departments and five centers. She has published numerous articles in refereed journals and edited texts and has spoken extensively both nationally and internationally on the subjects of emergent literacy, phonological awareness, and psychometric considerations in assessment as well as the relation between language development and reading development. Her most current research is in the scholarship of teaching and learning.

Introduction

This paper describes a research project on the success of students deemed to need remedial help in a mathematics course. The objective of the study is to compare success between two groups of remedial students to test whether remedial students placed in the gateway liberal arts course with embedded just-in-time remediation achieved the same success rates as remedial students placed into the course without embedded just-in-time remediation. Both courses are the gateway course, the first mathematics course taken by a student required for their intended major or program of study. Four pathways exist through which students complete the gateway mathematics courses needed for graduation. The four pathways are Liberal Arts, Statistics, Education, and STEM. For the Liberal Arts pathway students take Survey of Math (MA105) which is intended to support students' liberal arts and social science interests, by investigating applications of mathematics in contexts which are relevant to individuals without strong interests in mathematics. This course and a variant of it, the pilot of Survey of Math (MA105X), are the focus of this study. The paper discusses how students place into the courses, how the pilot offering of MA105X was designed, and the results of this comparison study.

Overview of the Problem

Nationally, a student who begins college in need of remediation in mathematics is unlikely to graduate on time and incurs additional costs for remedial courses, often leading students to become discouraged which can result in a failure to persist. Students demonstrate persistence when they obtain a Bachelor's degree despite obstacles including remedial courses. One reason students need remediation is that they arrive without the ability to perform academically in college-level courses. This gap in a student's ability is closed when the student successfully completes remedial courses and is declared college-ready. Nearly 25% of incoming freshmen at all types of institutions arrive not college-ready (Parsad and Lewis 2003). The number of students attending postsecondary institutions has grown to 21 million full-time students in 2011 from 15.9 million in 2001 (Snyder and Dillow 2011). Unprepared and underprepared students account for remediation costs estimated between $1 billion and $2 billion annually (Bahr 2008, Tierney and Garcia 2008). Reducing the need for remediation and the costs incurred is a focus at many institutions of higher learning (Shelton and Brown 2010). Often students placed into remedial course(s) drop out before enrolling in a college-level course (Bailey et al. 2010). Parsad and Lewis (2003) find that the sequence of remedial math courses ranges from one course to five or more, with an average of 2.5 courses. Bailey and Jaggars (2016) report only 11% of students with three remedial courses in their required sequence complete a gateway course within three years. Other students find the cost of remediation, which increases with the number of courses

in the remedial sequence, prohibitive. Additionally, research has questioned the validity of the placement tests used to determine incoming students' needs for remedial courses (Scott-Clayton 2012).

Efforts to reduce the need for remediation and increase persistence and completion rates currently receive a great deal of attention in higher education institutions, including the one where this study took place. Types of programs aimed at addressing the remedial-needs problem include shorter remedial course sequences, often based on pathways, co-requisite models (taking developmental courses at the same time as college-level courses), and modularized models (individualized remediation). Recent results on pathways from the Dana Center compared a single-semester remedial course designed to meet the needs of students on pathways for statistics, quantitative reasoning, and calculus to a traditional two-course algebra-based remedial course sequence (Rutschow et al. 2017). This qualitative study finds that, when compared with students on the two-course algebra-based remedial path, students in the single semester remedial course tended to have positive or highly positive perspectives of their math classes and view their learning more connected to their everyday lives.

Bickerstaff et al. (2016) examine modularized models in North Carolina and Virginia and find tensions between student autonomy, mastery, and acceleration on one hand and the need for institutions to match students with their optimum delivery format through advising on the other. The pressure to address the remedial problem is so great that some states, including Florida, have legislated how many students can participate in remedial programs and for how long (Hu et al. 2014).

With these challenges in mind, this study is designed to determine if embedded remediation accelerates the pathway to completion of a college-level math course. Prior to this study, students at our institution were placed into college-level courses based on a policy set by the Commonwealth of Massachusetts Board of Higher Education policy dating back to 1988. This policy mandated that all students within the state system take the College Board's Accuplacer placement exams. The policy applied to all state institutions, including community colleges, state universities, and the UMASS system; it set the cut-off scores for college readiness in mathematics. Students with a cut-off score of 82 on the elementary algebra placement exam were deemed college-ready and were eligible to enroll in a first-level college mathematics course known as the gateway math course. In 2001, this policy was amended to allow individual schools to set a cut-off score of 72 for students in non-algebra-based courses, including quantitative reasoning and statistics.

To increase the percentage of incoming freshman passing their gateway math class and to investigate alternative placement processes, the Massachusetts Board of Higher Education began a new placement program in 2013 (Vision Project 2013). The Department encouraged state institutions of higher education to pilot

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programs that place students into a gateway math course based on their overall high school GPA rather than relying on the Accuplacer alone. The state decided that students with an overall high school GPA of 2.7 or higher on a four-point scale are ready for college-level courses. The Department asked institutions to develop pilot programs using this criterion and then report back on the results. A pilot program at one of the state universities is the focus of this paper.

Worcester State University Pilot

The pilot at Worcester State University (WSU) was created based on the state's recommendations and a mandate by the administration at the University. We used many concepts from design-based research as we moved research from observation to the engineering of a solution (Barab and Squire 2004). The setting for the research is a real educational context; the intervention was designed and tested, and the research plans include multiple iterations—all in keeping with design-based research (Anderson and Shattuck 2012).

The setting for the study is an urban, state university with an undergraduate student population of 4,157 full-time students and 1,406 part-time students. In 2014, 794 first-year students entered the University. Four pathways exist through which students complete the gateway mathematics courses needed for graduation: Liberal Arts, Statistics, Education, and STEM. The shares of students on each of these pathways are 36%, 23%, 8%, and 33%, respectively (Factbook 2015).

Table 1
Mathematical Pathway by Major

Pathway	Major
STEM	Biology
	Biotechnology
	Business Administration
	Chemistry
	Communication Science & Disorders
	Computer Science
	Mathematics
	Natural Science
	Undeclared
Liberal Arts	Communication
	Criminal Justice
	English
	Geography
	Health Education
	History
	Occupational Studies
	Psychology
	Sociology
	Spanish
	Urban Studies
	Visual and Preforming Arts
Statistics	Community Health
	Economics
	Nursing
Education	Early Childhood Education
	Elementary Education

Table 1 shows the designated pathway for each major offered at WSU. The Mathematics Department chose to implement the mandated pilot in the Liberal Arts pathway course, Survey of Mathematics (MA105), for two reasons. First, it is terminal, meaning it is not a prerequisite for any other mathematics courses. So, any unintentional losses in student learning caused by the pilot would not create complications in subsequent required mathematics coursework. Second, the department felt that implementation in the Liberal Arts gateway could potentially benefit the most students if successful and harm the fewest if not.

Under the pilot program, the administration mandated how students would be placed into the gateway courses based on the needs of the registration process, high school GPA, and placement test scores. (See Fig. 1.) First, all students took two Accuplacer placement exams, Arithmetic and Elementary Algebra. Students with a high school GPA of less than 2.7 and all students on non-liberal arts pathways were placed based on their placement scores only according to existing placement criteria. These students' placements put them outside the scope of our study.

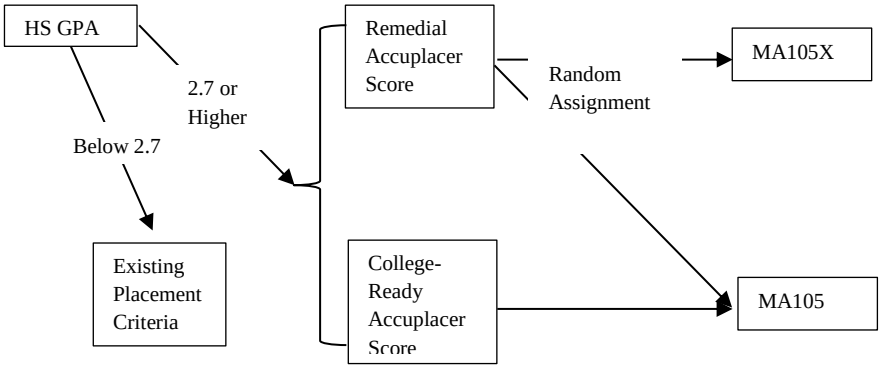

Figure 1. Pilot project liberal arts pathway placement process

Next, students who identified as liberal arts majors, had a high school GPA of 2.7 or greater, and who earned Accuplacer scores commensurate with a college-level placement were placed into the traditional version of the Liberal Arts pathway course, MA105. These students are also excluded from our study.

Finally, students who identified as liberal arts majors, had a high school GPA of 2.7 or greater, and who earned lower Accuplacer scores were randomly placed into either the pilot course MA105X or the college-level MA105. The administrative office responsible for placement testing performed the random placement into MA105 and MA105X; the mathematics department had no visibility into the process.

The mathematics faculty and its administration designed the pilot MA105X course based on the existing, successful remedial program. Through placement process awareness, the proportion of students needing remediation decreased by 50% (Bisk et al. 2013). For this reason, the decision was made to continue having all incoming students take the math placement exams for arithmetic and elementary algebra. The placement scores earned on these exams were used for assessment not placement purposes, and enable comparisons to prior years. Moreover, refinement of practices in the remedial course had proven very successful: the proportion of students passing the course rates had increased from 30% to 80%. As we implemented the pilot, we did not want to lose these gains, and so we incorporated

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several key features from the existing program: smaller class size, dedicated tutoring, and instructors dedicated to remedial students' success.

First, the maximum class size was set to 25 as compared to 32 in all other gateway math courses. Numerous benefits arise from a smaller class size. More interaction between instructors and students occurs, and comfort in the class setting increases, which benefits students given the amount of small group work expected.

Next, as reported with the existing remedial courses, in the pilot course tutoring played a key role. In previous work, remedial students reported they benefit from drop-in tutoring and that this contributes to their success (Bisk et al. 2013). Students report they like the dedicated tutors and find the environment non-threatening. Tutor selection and training followed the model used in the remedial program. Based on faculty feedback in the remedial program, students reported they benefited most from drop-in tutoring rather than more formal group tutoring. Typically the remedial program hires and trains students who are math majors with a career path in secondary math education or elementary education majors with a math focus. The pilot employed several trained remedial tutors to ensure an understanding of remedial students' needs. Tutoring was available for 20 hours each week to reach the majority of students. Tutors allowed students to struggle with problems and did not just give the answer. Students who failed the first mid-term were mandated to attend tutoring for a minimum of two hours per week. All 20 hours of tutoring were available to both MA105 and MA105X students; however, mandatory tutoring only existed for MA105X students.

Tutor training was critical. The MA105 course only exists on the Liberal Arts pathway and is not typically taken by the prospective tutors whose majors require either the Education or STEM pathways. The tutors each completed all of the assignments in the online homework framework used, MyMathLab. Throughout the term, the faculty team teaching the course met with the tutors to address any concerns and share student feedback.

Third, the pilot employed instructors familiar with the remedial program who were committed to the success of students with remediation needs. In preparation for the pilot, faculty who had demonstrated familiarity and commitment to remedial student success were recruited to teach the courses. The instructor team consisted of the course coordinator, the remedial program director, and three other professors with both MA105 and remedial experience. The faculty team met before and throughout the semester to maintain consistency throughout the pilot.

Finally, following the successful model of the existing remedial track, the program embedded remediation in a just-in-time manner where appropriate. The content and method of just-in-time interventions are described in detail below.

The credits earned for the two courses differ. Three college credits are earned upon successful completion of MA105 course while MA105X earns four credits in total: one remedial credit and three college-level credits. It should be noted that

remedial credits count toward full-time student status, but do not count toward the graduation credit requirement. The one additional credit hour allowed time for embedding remedial material into the course. The content, standards, and completion criteria of MA105 and MA105X were identical.

Embedded Remediation

The pilot embedded remedial topics and skills in a just-in-time manner; just-in-time refers to the introduction of a remedial topic immediately before beginning a college-level topic that requires that skill. The liberal arts mathematics course, MA105, includes five topics: Set Theory, Number Representation and Calculation, Personal Finance, Counting Methods and Probability Theory, and Voting and Apportionment. For each of these five topics the team assessed the remedial needs of students in the MA105X course, then defined and designed the common remedial content based on the basic mathematical skills required for each. Additionally, to help students meet the learning objectives of the course, problem sets were designed for each topic that integrated the remedial concepts.

MA105X Embedded Remediation by Topic.

Topic 1: Set Theory
Remediation focused on the symbols and their meanings, including subset and basic set terminology. Additionally, remediation focused on word problems where the representation of survey data used Venn diagrams.

Topic 2: Number Representation and Calculation
Remediation focused on place value, scientific notation, expanded form, and operations in base ten. Once students obtained comfort with base-ten operations, other bases were introduced.

Topic 3: Personal Finance
Remediation focused on percent, decimals, percent to decimal conversions, percent increase and decrease, order of operations, simple interest and formulas. With this topic we also emphasized how to approach word problems. Remediation here highlighted the need to show all your work and to check it, and showed students how to determine if the answer made sense.

Topic 4: Counting Methods and Probability Theory
Remediation focused on a review of fractions and the relationship between fractions and decimals. Factorial operations were also covered. The probability and statistics functions on a scientific calculator were also covered.

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Topic 5: Voting and Apportionment
Remediation focused on rounding and interpreting data from tables. Instructors emphasized when an apportionment amount is within one of the natural quota and the need to review all work to satisfy the completion criteria and understand the paradox.

Methodology

The research project was not a designed experiment and used retrospective analysis. In the summer of 2014, 794 incoming first-year students were tested using the Accuplacer tests. Students on the Liberal Arts pathway were placed by the testing administrator who decided the placement based on Accuplacer scores, high school GPA, and major following the process in Figure 1 above. (Faculty in the Department of Mathematics played no role in placement.)

Marginally-prepared students were spread through all sections of MA105 so that each section was a mix of college-ready and marginally-prepared students. The administration placed approximately equal numbers of marginally-prepared students in MA105 and in MA105X. No effort was made to assign students to MA105 or MA105X based on any other factors such as class meeting time, major, or instructor. No more details about this placement were made available and instructors were not informed whether any individual student was college-ready or marginally-prepared.

In an attempt to control the variability between the MA105X and MA105 groups and within each group, common materials and assessments were used. The materials included a workbook developed by the course coordinators over the past few years. All homework assignments were common and in the MyMathLab platform provided by Pearson. Assessments were common and consisted of multiple versions of two midterms and a final exam. The faculty team developed all of these assessments as a group with the course coordinator. The faculty team consisted of three MA105X and five MA105 instructors. All but one had taught the classes before so most were experienced and familiar with the materials. Common grading standards were used for each assessment. Given our small sample size, no attempts were made to account for possible difference attributable to factors such as scheduled class time, student majors, or high school GPA.

Results

There were 79 students who were identified as marginally-prepared and placed into either MA105 or MA105X in the fall 2014 semester. They were randomized between MA105X and MA105 with 39 students in the former MA105X and 40 in the latter. The students' final grades are shown in Table 2. The number of A's was higher for the MA105X group than the MA105 group, while there were fewer B's but more C's, about the same number of D's and far fewer E's and F's.

Table 2
Cross-Classification of Students by Class Assignment and Final Grade

Final Grade	MA105	MA105X
A, A-	6	10
B+, B, B-	14	12
C+, C, C-	8	10
D+, D, D-	5	4
E, F	5	1
P	1	2
W	1	0
Total	*40*	*39*

Table 3
Cross-Classification of Students by Class Assignment and Passing Status

Final Grade	MA105	MA105X
Passing (A,B,C,D,P)	34 (85%)	38 (97%)
Not Passing (E,F,W)	6 (15%)	1 (3%)
Total	*40 (100%)*	*39 (100%)*

Table 4
Cross-Classification of Students by Class Assignment and DFW Status

Final Grade	MA105	MA105X
Not DFW (A,B,C,P)	29 (72.5%)	34 (87.2%)
DFW (D, E, F, W)	11 (27.5%)	5 (12.8%)
Total	40 (100%)	39 (100%)

We define passing as any grade other than E, F or W. Table 3 cross-classifies the MA105 or MA105X students by their class assignment and their passing/not passing status. Higher numbers and percentage of students earned passing grades in MA105X than in MA105.

Due to the small number of students not passing in MA105X, we used the Fischer exact test to test the hypothesis of equality of proportion rather than the *z*-test of independent proportions. The Fisher exact test yields a *p*-value of 0.108. Of course, a D grade is a low standard of success. Table 4 replicates the analysis in Table 3 with a slightly higher definition of success: C- or better. The results are qualitatively similar to those in Table 3: more students in MA105X achieved success than those in MA105. To test the hypothesis that the proportion of students earning a grade of D, E, F, or W in MA105 is equal to the proportion of students earning a grade of D, F or W in MA105X, we performed a *z*-test of independent proportions. The *z*-test yielded a *p*-value of 0.098.

Since both *p*-values are close to 0.1, we conclude that further investigation is needed to determine if success rates in MA105 and MA105X are significantly different. This is particularly important given that the effect sizes are practically large. For example, just over one-quarter of MA105 students fell short of a C-grade. The additional support in MA105X cut that failure rate in half. However, we feel that the study provides good evidence that MA105X is successful and most likely does no harm to full-time students who do not pay for the additional credit hour.

Conclusion

This study was designed to determine if embedded remediation is significant in accelerating the pathway to completion of a college-level math course for students needing remediation, specifically for students in a liberal arts course of study. A mandatory extra hour of instruction was added to a general education mathematics

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course. The original course topics were not changed. The extra hour was devoted to covering the developmental material necessary to understanding the college-level course content.

We find that 87% of students succeeded (at a level of C- or better) in the course with embedded remediation compared to 72.5% of those in the traditional version of the course. Though the difference is not statistically significant, the point estimate suggests that embedded remediation may have reduced the failure rate by approximately half. Overall, the research project indicated further study is needed to determine if embedded remediation is significant for accelerating the pathway to completion of a college-level math course for remedial students. However, we feel that the study provides good evidence that course with embedded remediation (MA105X) benefits students and does no harm to full-time students. The only students at a disadvantage in MA105X are part-time students because these students must pay for an additional credit hour.

As educators, we feel our students come first and, when examining the pilot's outcomes, were concerned about students needing remediation who were placed into the MA105 course. Specifically, we were concerned that without remediation students who did not succeed were being put at risk. After the semester we followed up with the seven students in MA105 and MA105X who earned an E or F and offered them the option of retaking MA105 with additional instructor support. Six of the seven chose to take MA105 again and passed. Even though these students required two course attempts to complete the course, their path resulted in a course sequence equal to or less than the remedial path they would have taken under the placement process prior to the pilot. It should be noted the seventh student left school for personal reasons.

These results suggest that embedded remediation has the potential for significant reduction in course-taking burdens for marginally-prepared students. If all 79 students had been assigned to MA105X, they would have accounted for 79 credit-hours of remediation work. Because full-time students do not pay for the additional credits, the actual cost to students would have been even less than this (though the cost is clearly borne by the instructor). Based on our experience, on average two of these students would earn less than a D in their first attempt, and these would likely succeed on a second attempt. Adding the 8 credit-hours associated with these second attempts, the total remediation work comes to less than 100 credit hours. Had these 79 students instead taken the traditional remediation course(s) prior to MA105 enrollment, they would have consumed more than 350 credit-hours in remediation. If the results reported in this paper persist with replication, the approach of embedded remediation could produce significant savings to both students and institutions.

Changes to the remediation coursework, driven by the administration, continue based on the high school GPA of 2.7. In fall 2015, all students in the liberal arts

pathway with a high school GPA of 2.7 or higher but low Accuplacer test scores were placed in MA105X with embedded remediation. In fall 2016 semester, all such students were placed in MA105 without embedded remediation. Success rates in the fall 2016 and fall 2015 semesters will be compared to further study the importance and impact of embedded remediation.

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