Snowballing: The Unexplored Issue of Developmental Mathematics and Course Repetition

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In the developmental mathematics education literature, course failure typically leads only to attrition from the course sequence. That is, an overlooked, and not well-understood, experience in developmental mathematics, is course repetition. In this quantitative study, I aimed to investigate the incidence and impact of developmental mathematics course repetition. Specifically, I aimed to document how experiences with course repetition contributed to students' course taking patterns within and beyond developmental mathematics. Findings indicate that the consequences of experiences with developmental mathematics course repetition are significant and far reaching, influencing longer-term academic outcomes including program retention and degree attainment. The need for further investigation, particularly using qualitative methods to understand how and why observed relationships in a student's mathematics/academic trajectory operate and function, is well supported by the quantitative results of this study.

Keywords: Developmental math, course repetition, STEM students, graduation rates

While developmental mathematics (DM) education aims to resolve preparatory disparities and provide a path for degree attainment, research has consistently documented poor academic outcomes among DM students at both two- and four-year institutions (Bahr, 2010; 2012). Short-term outcomes include high rates of course failure and sequence attrition, while longer-term outcomes include longer times to and lower rates of degree attainment (Bailey et al., 2010; Chen, 2016; Fong et al., 2015). Furthermore, despite consistent empirical (e.g., Bailey et al., 2010; Bahr, 2012) and anecdotal (e.g., from instructor practitioners) evidence that DM courses suffer from high rates of failure, the significance and influence of DM course repetition[1] on these outcomes is unaccounted for in the extant DM education literature. In this study, the term *contextual force* refers to a phenomenon that is, in some way, inherent to the learning context, and that indirectly, though importantly, shapes the learning context. Given the high rate of failure documented in DM courses, experiences with course repetition are inherently a part of the DM educational experience. As such, this study asserts that DM course repetition is a contextual force that influences DM education and its outcomes by its direct impact on students and their learning experience.

Literature Review

In Bahr and colleagues' (2017) mapping of students' STEM course taking pathways, reported course outcomes (e.g., pass rate, failure rate, STEM pathway attrition, etc.) only concerned students' performance in their first attempt of a course, explicitly excluding students' performance during subsequent course attempts from analysis and reporting. According to Bicak and colleagues (2023), though more documented in K–12 education research, the rates and implications of course repetition are not well-explored in postsecondary education research. In

[1] *Developmental mathematics course repetition* is defined in this study as the enrollment in a course previously taken because the prior enrollment ended with a failing final grade, withdrawal from the course, or a final grade lower than what is needed to advance to the next course in the sequence.

particular, much of the research investigating DM education is anchored at two-year postsecondary institutions, meaning there is a need for DM education research conducted at four-year postsecondary institutions. Furthermore, while there is significant concern among developmental mathematics researchers regarding DM sequence attrition and completion, few, if any studies, have endeavored to conceptualize or understand the factors (including their functioning and underlying mechanisms) that contribute to attrition or completion. For instance, Bahr (2008) found that the likelihood of successful remediation–operationalized as passing college-level coursework–is inversely related to level of placement, or "depth of remedial need" (p. 444): The lower a student's placement, the lower the likelihood of the student passing college-level coursework. When discussing this finding, Bahr acknowledged that "the mechanisms that underlie the relationships between depth of remedial need and successful remediation are, as of yet unclear" (Bahr, 2008, p. 444). This underscores that the lack of a fundamental understanding of factors that contribute to observed outcomes relating to sequence attrition or completion inhibit the advancement of DM research.

To address this gap in knowledge, this study seeks to answer the following questions:

1. What are the rates and patterns of developmental mathematics course repetition?
    a. What are the mathematics course taking trajectories and longer-term academic outcomes of students who experience developmental mathematics course repetition?

Research question 1a is motivated by Hodara's (2019) finding that DM students are less likely to retain their STEM major than their non-developmental peers. While this finding was not discussed further, program retention is likely related to DM sequence attrition, given the findings regarding gatekeeper course enrollment and completion. As such, this study seeks to investigate how DM course repetition impacts program retention and graduation.

Methods

Data Collection

Data collection occurred at Temple University— a large, four-year, public research university in a large city on the East Coast. I obtained longitudinal student data from the Temple's Office of Institutional Research and Assessment for developmental mathematics course enrollees who entered Temple between the 2013-2014 (13-14) and 2023-2024 (23-24) academic years. The data set included course and program enrollment data, as well as graduation information. Data cleaning yielded an analytic sample of 14,942 students whose enrollment (e.g., campus of enrollment) and academic records (e.g., DM coursework was taken either in-person or virtually during the pandemic) met certain criteria, which ensured uniformity aligned with the scope of this study's investigation. I used subsets of this analytic sample for more precise analyses, which are discussed below.

The Temple mathematics department currently offers three algebra-focused courses—MATH 0701, 0702, and 1021—and one co-requisite laboratory course—MATH 1019—associated with the highest-level algebra course, MATH 1021. That said, given the purpose and functioning of DM education at Temple University—particularly the prior changes to MATH 0701 and the more recent addition of MATH 1019—MATH 0702 Intermediate Algebra and MATH 1021 College Algebra are the DM courses of primary interest in this analysis. Furthermore, this study is interested in the academic trajectory of DM students and their engagement with advanced/college-level mathematics courses, specifically the calculus sequence, which at Temple involves four calculus courses starting with Precalculus. Relatedly, I examined how and when DM students' program of enrollment shifted, if at all, during or after their DM coursework.

In particular, I was interested in DM students who enrolled in a STEM or STEM-adjacent program, referred to as *STEM (adjacent) programs* (e.g., Music Technology or Secondary Education), at some point in their time at Temple because calculus coursework is a requirement only for certain STEM (adjacent) programs.

Data Analysis

To answer research question 1 pertaining to rates and patterns associated with DM course repetition, I established enrollment trends, including most frequent DM course sequences, by analyzing the analytic sample of 14,942 DM students. I then analyzed a more uniform subset of DM students (n=10,482) to establish rates and frequencies of DM course repetition. Chen (2016) found high rates of continued enrollment among remedial students 6 years after initial enrollment, suggesting these students might take longer to complete their degree. As such, to answer research question 1a pertaining to the longer-term academic outcomes of DM students, I analyzed the 5,765 students who enrolled at Temple between the 13-14 and 18-19 academic years because their academic records span at least 6 academic years (Figure 1).

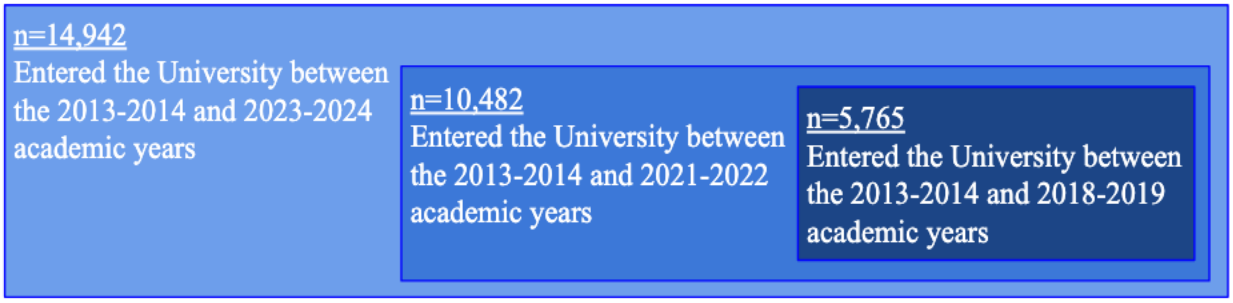

Figure 1. Analytic Samples

Results

Of the 14,942 developmental mathematics students of interest with initial enrollment data (n=14,279), 90.15% took their first DM course during their first year of enrollment, 97.76% within their first two years of enrollment, and 99.36% within their first three years of enrollment. 9,958 students enrolled in 1 DM course, 4,679 students enrolled in 2 DM courses, 302 students enrolled in 3 DM courses, and 3 students enrolled 4 DM courses. 14,932 students enrolled in course sequences of interest (Figure 2); The exclusions involved anomalous course sequences and too few enrolled students for analysis. 25.14% of DM students had to repeat at least one (and up to three) of their DM courses and 20.71% (n=778) of DM repeaters had to repeat one of their DM courses more than once. For instance, a student could take 3 DM courses, repeat two of those courses one time each, and have a DM sequence length[2] of 5 (referred to as a *singular repeater* or *repetition*), or a student could take 1 DM course, repeat the course four times, and have a DM sequence length of 5 (referred to as a *multiple repeater* or *repetition*). Thus, while singular repeaters have longer DM course sequences because of one course repetition per repeated course, multiple repeaters have longer DM course sequences because they repeated a course(s) multiple times. Such instances of multiple repetitions are highlighted in orange in Table 1, which summarizes DM sequence length according to how many DM courses students enrolled in and had to repeat.

[2] *DM sequence length* refers to a student's total number of DM course enrollments during their time at Temple.

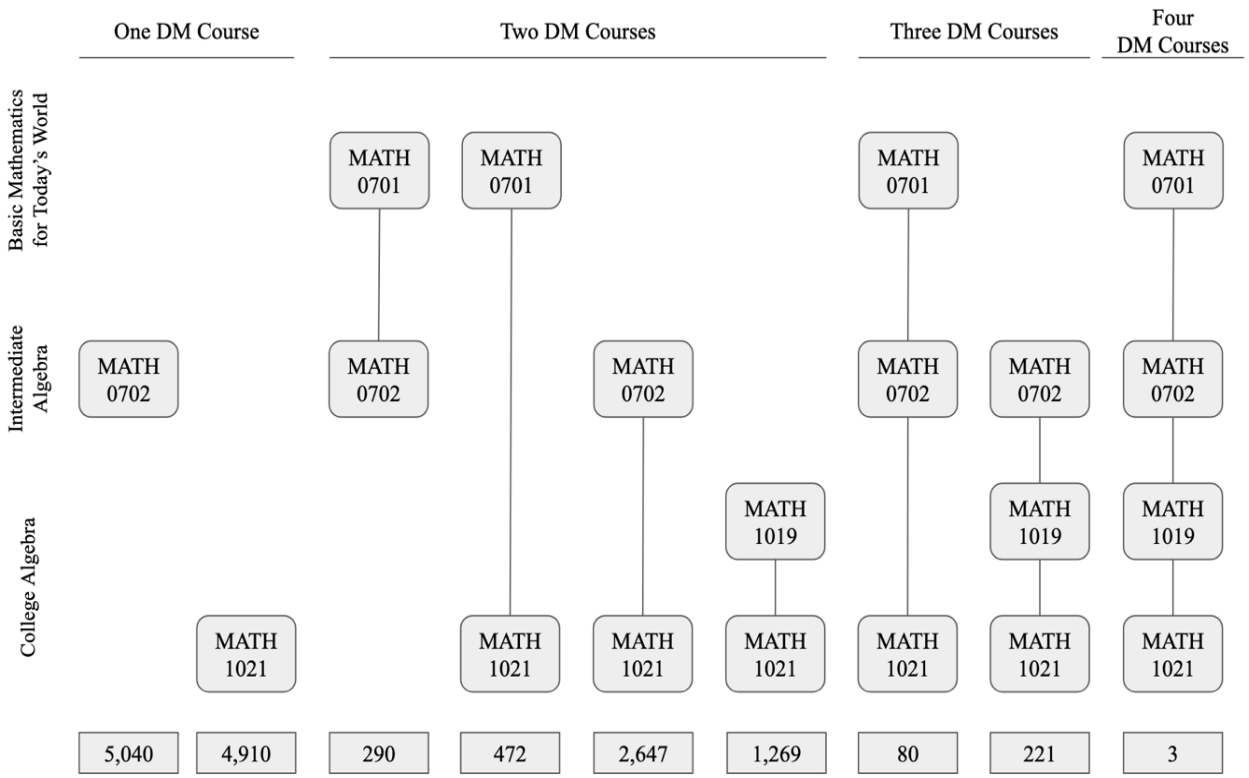

Figure 2. Most Frequent Developmental Mathematics Course Taking Patterns

Table 1. Developmental Mathematics Course Enrollments

Number of Enrolled DM Courses	Number of DM Courses Repeated	DM Sequence Length								**Total**
		1	2	3	4	5	6	7	8	
1	0	7,818	0	0	0	0	0	0	0	**7,818**
1	1	0	1,759	371	9	1	0	0	0	**2,140**
2	0	0	3,251	0	0	0	0	0	0	**3,251**
2	1	0	0	911	246	7	0	0	0	**1,164**
2	2	0	0	0	180	68	16	0	0	**264**
3	0	0	0	115	0	0	0	0	0	**115**
3	1	0	0	0	76	40	0	0	0	**116**
3	2	0	0	0	0	42	14	4	0	**60**
3	3	0	0	0	0	0	9	1	1	**11**
4	0	0	0	0	2	0	0	0	0	**2**
4	1	0	0	0	0	1	0	0	0	**1**
	Total	**7,818**	**5,010**	**1,397**	**513**	**159**	**39**	**5**	**1**	**14,942**

Of the more uniform subset of 10,482 DM students and across all their DM enrollments, 742 students withdrew from at least one of their DM courses, 2,510 students failed at least one of their DM courses, and 326 students experienced both at least one DM course withdrawal and at least one DM course failure. 34.05% of students who experienced both DM course withdrawal

and failure experienced more than one withdrawal and/or failure. Table 2 summarizes the passing rates in MATH 0702 and 1021 based on enrollment attempt. 16.83% of MATH 0702 students (n=5,756) repeated the course at least once and 20.84% of MATH 1021 students (n=6,709) repeated the course at least once. Of the 1,985 students who took both MATH 0702 and 1021, while the rate of MATH 1021 repetition among students with no repetitions of MATH 0702 was 21.91%, the rate of MATH 1021 repetition among students with at least one repetition of MATH 0702 was 45.69%. Of students' final DM course enrollment, 78.63% of students passed, 14.44% failed, and 6.36% withdrew from their final DM enrollment.

Table 2. Final Course Grade by Course and Attempt

	MATH 0702			MATH 1021		
	1st Attempt (n=5,756)	2nd Attempt (n=969)	3rd Attempt (n=146)	1st Attempt (n=6,709)	2nd Attempt (n=1,398)	3rd Attempt (n=271)
Pass [a]	69.96%	57.07%	50.00%	70.52%	63.16%	69.37%
Fail [b]	20.64%	30.65%	34.93%	22.58%	29.83%	25.46%
Withdraw	8.60%	11.87%	13.01%	6.68%	6.44%	4.43%

Note: Course attempts were included if enrollment was greater than 100. [a] Pass = A to C-. [b] Fail = D+ to F.

Of the 5,765 DM students who enrolled Temple between the 13-14 and 18-19 academic years, 3,023 were enrolled in a STEM (adjacent) program during their last DM course enrollment. Additionally, 1,933 of the 13-14 to 18-19 entering students enrolled in at least one calculus sequence course—referred to as *DM-to-calculus enrollees*—following their last DM course enrollment. While 57.07% of STEM (adjacent) students who did not experience DM course repetition became DM-to-calculus enrollees, lower rates of DM singular repeaters and DM multiple repeaters became DM-to-calculus enrollees—27.05% and 23.58%, respectively; Table 3 summarizes the final course grade of DM-to-calculus students' first calculus sequence course differentiated by the extent of repetition in DM coursework. 83.29% (n=1,610) of DM-to-calculus enrollees were enrolled in a STEM (adjacent) program during their last DM course enrollment and 65.09% (n=1,048) of these DM-to-calculus enrollees retained their STEM (adjacent) program enrollment throughout their time at Temple.

Table 3. Final Grade in First Calculus Course Following DM Course Sequence

	No Repetitions (n=2,842)	Singular Repetitions (n=504)	Multiple Repetitions (n=85)
Pass	58.09%	26.79%	14.12%
Fail	28.36%	46.03%	57.65%
Withdraw	12.91%	26.39%	28.24%

Of the 13-14 to 18-19 entering students, 3,804 (65.98%) graduated. The graduation rate among students who repeated 0, 1, or 2 DM courses was 68.12%, 58.97%, and 57.35%, respectively. Table 4 summarizes overall graduation rate by extent of DM repetition and further differentiates graduation rates by time to degree attainment. Of the 1,889 graduates who began their DM coursework enrolled in a STEM (adjacent) program, 47.70% graduated with a STEM (adjacent) degree, which suggests that the rate of STEM (adjacent) program attrition amongst graduates is more than 50%. The students who retained and graduated with a STEM (adjacent)

degree account for 81.54% of students who graduated with a STEM (adjacent) degree, suggesting that relatively few students transfer into STEM (adjacent) programs from non-STEM (adjacent) programs; The STEM (adjacent) program retention rate amongst non-graduates (n=1,189) was 74.10%. The rate of STEM (adjacent) program retention from initial enrollment through graduation varied based on experience with DM course repetition: While the program retention rate was 51.48% among students who did not repeat a DM course, the program retention rate among singular and multiple repeaters was 34.57% and 36.59%, respectively.

Table 4. Graduation Rate and Time to Degree Completion

		Years to Degree Completion				
	Graduation Rate	<4	4	5	6	6+
No Course Repetitions	68.12%	7.29%	57.47%	26.57%	6.69%	1.99%
Singular Repetitions	60.26%	4.43%	42.29%	38.63%	11.45%	3.21%
Multiple Repetitions	52.85%	3.08%	27.69%	41.54%	20.00%	7.69%

Discussion and Conclusion

In working to investigate the rates, trends, and long-term impacts of course repetition in developmental mathematics education, it became quickly evident that the consequences of repetition are numerous and cumulative. Analyses reveal that more than a third of students receive a non-passing final grade at some point in their DM coursework and that more than a fifth of students receive a non-passing grade in their last DM course. Furthermore, while prior research has documented the high failure rates of DM courses (e.g., Bahr, 2012), this study's analyses reveal that DM courses' passing rates decline across enrollment attempts. Taken together, these findings highlight the precarious pathway DM students must traverse to pass or advance further than their DM coursework.

It is clear from this study's results that the impact of DM course repetition extends beyond a student's DM coursework. In particular, the extent of a student's experience with DM course repetition appears to impact further mathematics persistence and performance. While these quantitative analyses do not and cannot provide much insight into how the former finding functions, it is nevertheless a meaningful finding that should motivate future efforts to reduce DM sequence and STEM (adjacent) program attrition. The latter finding that first-calculus course passing rates decrease with experiences with DM course repetition suggests that the efficacy of DM education wanes as students repeat courses. Experience with DM course repetition also appears to impact timely degree attainment, which is a reasonable finding given that multiple repetitions can double or even triple the length of a student's DM course sequence relative to the number of DM courses in which they enroll (e.g., taking 2 DM courses, repeating both twice, and having a DM course sequence length of 6). Furthermore, the findings regarding STEM (adjacent) program attrition and retention through degree attainment—that program retention is low, yet the rate of students transferring into STEM (adjacent) programs is seemingly lower—suggest that addressing the high incidence of DM course repetition could be an effective means of increasing STEM (adjacent) program retention, since there is evidence that DM course repetition is related to post-DM persistence. Specifically, by conducting this study at Temple—a STEM-focused, research institution, where DM coursework is a remedial prerequisite for more advanced mathematics coursework—this study not only contributes to the growing body of DM

education research conducted at four-year institutions, but it also provides insight into how DM education relates to and impacts STEM (adjacent) trajectories.

Implications, Limitations, and Next Steps

This study's findings underscore the significant financial, opportunity, and psychic costs incurred by students when they encounter this common, yet not well-understood, experience within DM education. Specifically, extended course sequences cost students time and money in pursuing their program, degree, and career path. Furthermore, considering the tenuous—though well-studied—relationship students have with mathematics, it is important to consider how students experiencing DM course repetition perceive their learning experience and potential. Thus, a major limitation of this study is that its quantitative methodology provides little insight into how the academic, mental, and tangible costs interact to compound the consequences of DM course repetition. Additionally, unexpected quantitative results made it difficult to conduct certain analyses. For instance, students' course sequences were occasionally regressive (e.g., taking MATH 1021 and then later taking MATH 0701), or students sometimes advanced to higher-level DM courses without having passed the prior prerequisite course. Taken together, this study's findings strongly warrant qualitative investigations of students' experiences with course repetition to understand how and why observed trends and quantitatively inexplicable patterns occur. Furthermore, narrative reflections from DM students who have experienced course repetition could help inform instructional practice, as well. For instance, understanding students' perspectives on their repeated DM course enrollments, both cognitively and affectively, could help instructors differentiate their lessons. Thus, exploring DM course repetition qualitatively will support the investigation of this phenomenon as a contextual force that influences the DM educational environment via its impact on DM students' and their learning experience.

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