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Calculus Reform - Increasing STEM Retention and Post-Requisite Course Success While Closing the Retention Gap for Women and Underrepresented Minority Students

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Abstract

Boise State University (BSU) implemented an across-the-board reform of calculus instruction during the 2014 calendar year. The details of the reform, described elsewhere (Bullock, 2015), (Bullock 2016), involve both pedagogical and curricular reform. Gains from the project have included a jump in Calculus I pass rate, greater student engagement, greater instructor satisfaction, a shift toward active learning pedagogies, and the emergence of a strong collaborative teaching community. This paper examines the effects of the reform on student retention. Since the curricular reform involved pruning some content and altering course outcomes, which could conceivably have negative downstream impacts, we report on student success in post-requisite mathematics and engineering coursework.

To explore the effects of the Calculus reform on retention we focused on whether or not students are retained at the university immediately subsequent to the year in which they encounter Calculus I. We divided 3002 student records into two groups: those who encountered the new version of Calculus and those who had the traditional experience. We then compared retention rates for the two groups. We found that the new Calculus course improved retention (relative to the old) by 3.4 percentage points; a modest, but statistically significant ($p = 0.020$) result. University retention rates for women, under-represented minorities (URM), and Pell-eligible students were also computed. All three subgroups showed gains, with URM leading with 6.3 percentage points of improved retention ($p = 0.107$)

We then considered retention within STEM as a measure of how the Calculus reform influenced students. For the same groups of students, we computed the rate at which STEM majors were retained in STEM. Once again we found a modest overall gain of 3.3 percentage points ($p = .078$). We found strong effects on women and underrepresented minorities (URM). The new Calculus course improved retention for both of these groups by **more than 9 percentage points**, a large effect. At this university, under the old Calculus, women used to lag men in STEM retention by about 8 percentage points. After the Calculus reform this gap nearly vanished, shrinking to 0.5 percentage points. Under the old Calculus, STEM retention of URM students used to lag that of non-URM. After the Calculus reform the gap flipped, so that underrepresented minority students are now retained in STEM at *higher* rates than non-URM.

As a final result we examined student success in courses that typically follow Calculus I. Here the metric is pass rate, and we compared pass rates between the students who took the new Calculus against those who took the old. For additional comparison we also included students who transferred into post-Calculus course work. Once again the reformed Calculus course led to better results.

1.0 Introduction

The department of mathematics recognized a strong need to completely overhaul the instruction of Calculus at Boise State University (BSU). This need resulted from rapid growth in STEM enrollment that occurred which exacerbated underlying weaknesses in the calculus sequence. These weaknesses included first, a lack of alignment of content, despite the presence of a guiding master syllabus and common textbook; second, a lack of alignment concerning assessment, resulting in wide variations in pass rate between instructors of different sections of the same course (Bullock, 2015) and third, very low pass rates – for example, the average pass rate in 2005-6 was 51% (Callahan, 2009).

Transformational curriculum change requires a wide degree of faculty buy-in. The record of how our mathematics faculty engaged in the process is described elsewhere (Bullock, 2015); it was a process that was intrinsically motivated, it had funding that was used to create faculty learning communities that met across a year, and it was phased in mostly across the spring and fall semesters of 2014.

Gains from the project that have previously been reported include pass rate gains that range from 8 to 10%, increased satisfaction by instructors, students and clients, and a shorter prerequisite chain – students may enroll in trigonometry as a co-requisite. While previous work has examined student preparation for Calculus II and shown that the "reformed" Calculus I provides suitable preparation, we have not previously examined student retention. Nor have we examined student performance in post-requisite coursework beyond Calculus II. In this paper we track and report on performance in post-requisite coursework, including post-requisite coursework in Dynamics, Fluids, Calculus III and Differential Equations.

2.0 Background and Experimental Methods

2.1 Pedagogical Approach

The overhauled, or "reformed" Calculus I course (R-Calc) has significant pedagogical differences relative to how it had generally been taught prior to the overhaul (N-Calc). R-Calc devotes a majority of class time to students working in small groups on assignments that were designed along learning cycle principles to target one or two specific learning goals. In-class work is facilitated by the lead instructor and a peer learning assistant. Developing these in-class assignments was facilitated by organizing and holding year-long faculty learning communities (Bullock, 2015).

Whenever possible, students work with data sets and/or continuous models selected from actual physical, biological, financial or other applied models, using notation, language and conventions of the disciplines from which the models are taken. All content is accessible from an intuitive or practical viewpoint, resulting in less abstraction relative to what had been previously taught in N-Calc.

2.2 Experimental Methods

The primary goal of this study/paper is to measure the effect of the Calculus reform on student retention. There is a strong presumption that the math "pipeline" has a negative impact on student retention and especially on student retention in STEM majors. We neither question nor investigate that assumption here. Rather, we seek to measure the retention rates for students in the year during which they encounter Calculus I, with the aim of comparing the effects to two different Calculus experiences that they might have encountered.

> Q1: At what rate are students retained at BSU in the Academic year immediately subsequent to their enrollment in Calculus I?
>
> Q2: What, if any, is the difference in BSU retention rate between students who experience R-Calc versus those who experience N-Calc?
>
> Q3: At what rate are STEM majors retained in STEM in the academic year immediately subsequent to their enrollment in Calculus I?
>
> Q4: What, if any, is the difference in STEM retention rate between students who experience R-Calc versus those who experience N-Calc?
>
> Q5: What, if any, effect does R-Calc have on retention rates for URM, Women, Pell-eligible students?
>
> Q6: What, if any, effect does R-Calc have on pass rates in post-requisite courses?

Questions 1 and 3 are answered with descriptive statistics. The remaining questions ask whether a metric applied to students taking R-Calc differs from the same metric applied to students taking N-Calc. In all cases the metric is a simple proportion (pass rate or retention rate) so all of these questions are answered by testing the following null hypothesis:

> H_0: The [pass/retention] rate of students who took R-Calc is no different than the [pass/retention] rate of students who took N-Calc.

The alternative hypothesis is that the rates are different, either larger or smaller, so we will use 2-tailed *z*-tests. For Question 5 the hypotheses and tests are unchanged; we simply restrict the population.

2.2.1 The Retention Study Population

We gather data on students organized into four cohorts by academic year (AY). Academic years are named for the calendar year containing the spring semester and do not include summer terms. For example, AY 2013 consists of Fall 2012 and Spring 2013 semesters. For each AY, we include in the study all students who:

- Were enrolled for classes in the fall term.
- Were enrolled, as of 10th day, in a section of Calculus I in at least one of the two terms.
- We do not include honors sections and concurrent enrollment (high school AP classes).

Concurrent enrollment students are held out for the obvious reason that their retention is not relevant. Honors students are held out because there are no honors sections in R-Calc.

The most recent year for which data is available is AY 2016. We extend the study back 4 years so that we capture a balanced picture of calculus enrollments before the transition to R-Calc. As indicated in Figure 1, R-Calc was phased in during the study time frame. It was still an experimental course in AY 2013. Scale up began in AY 2014. Since then R-Calc has been the dominant form of Calculus I. The four-year time frame thus includes a reasonable amount of time on each side of the transition, and balances the total number of records as nearly as possible between N-Calc (1560 records) and R-Calc (1442 records).

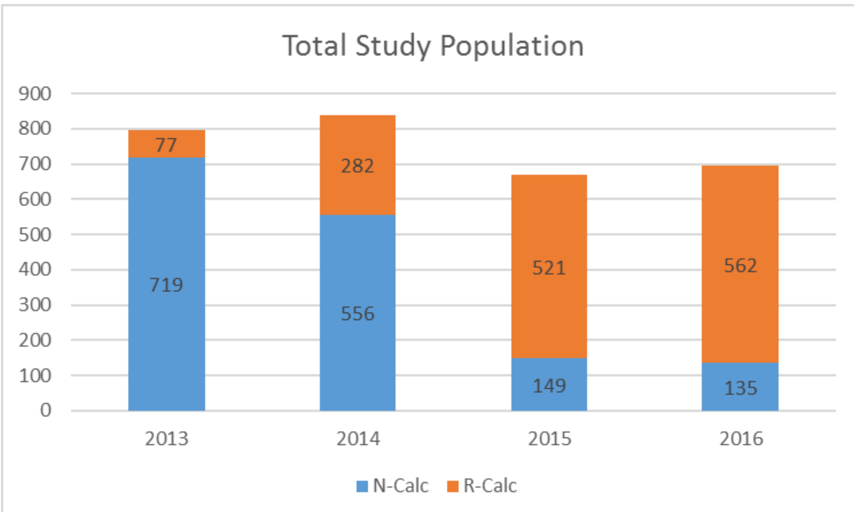

Figure 1: Number of students in N-Calc and R-Calc population

All retention results are presented using this data set aggregated across all four AY's. After checking every data set expanded into a time series we found no confounding trends. Including time series analysis adds little additional information.

2.2.2 Retention Rate Study[1]

Every record in the full data set includes a specified AY. The student in that record is considered "Retained at BSU" if they are enrolled in the fall term of the subsequent AY. However, we do not consider students who graduate during their cohort AY to be either retained or non-retained. Hence

<u>Retention Rate</u> for any subgroup is defined as[2]

= (Number retained at BSU) / (Number of records – Number graduating during cohort AY)

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[1] *Our definitions of the terms "cohort," "retention," and "retention rate" differ from their definitions in State University's official reporting.*

[2] *Note that this differs from traditional definitions of retention used by BSU's official reporting offices. For Federal reporting purposes, retention denominator is the full cohort, but typically only full time, non-transfer students. Further, official reports typically focus on first year retention, which makes graduation effectively impossible. Eliminating these students has a negligible effect on results, since of the 3,002 records in the data set, only 47 represent students who end up in the Graduated category.*

STEM Retention

To study STEM retention, we restrict each cohort or subgroup to those students who have a STEM major declared in the fall term of their cohort AY. For these students, there are four mutually exclusive outcomes that we track in the subsequent AY.

- Graduated = obtained a degree or certificate during the cohort AY.
- Dropped Out = not graduated and not enrolled in subsequent fall term.
- Stem-to-Stem = Retained, not graduated, and has a declared STEM major in the subsequent fall term.
- Stem-to-Non = Retained, not graduated, but does not have a STEM declared major in subsequent fall term.

We then compute three rates for any cohort or subgroup:

STEM Retention Rate

= (Number of Stem-to-Stem) / (Number of STEM Majors – Number Graduated)

Dropout Rate

= (Number Dropped Out) / (Number of STEM Majors – Number Graduated)

Leave STEM Rate

= (Number of Stem-to-Non) / (Number of STEM Majors – Number Graduated)

Students are split into those who encountered R-Calc and those who encountered N-Calc. We consider the former to be a treatment population and the latter a control population. The natural experiment allows us compare their retention rates to determine the effect of calculus transformation.

2.2.3 Course Pairs Study

To examine the effects of the reformed Calculus I curriculum on post-requisite math, physics and engineering courses, we study longitudinally paired courses: the first is always Calculus I and the second is one of:

- Calculus II
- Calculus III
- Differential Equations
- Physics
- Statics
- Dynamics
- Fluids
- Mechanics of Materials

We use a similar population for this study: all students who encountered these courses in the stretch form AY 2013 to AY 2016, but this time we include summer terms. The data set splits into those who used R-Calc as the prerequisite and those who used N-Calc. For these two groups we compare the pass rate in post-requisite courses. Again we have a natural experiment where the comparison of pass rates provides a measure of the impact of the calculus reform.

3.0 Results

The results section is divided into two major categories. First we discuss retention, looking at general retention (retained at BSU), and then we focus on STEM specific retention. In both cases we examine retention for women, URM, and for those who are Pell-eligible. The second major section concerns post-requisite course success, which we examine using course-pair data.

3.1 Retention

3.1.1 General Retention Rates – Retained at BSU

Our first result is a comparison of general retention rates for R-Calc versus N-Calc. The top row of Table 1 shows the retention of all students after R-Calc compared to those who encountered N-Calc. Subsequent rows show the comparative retention rates for women, URM, and Pell-eligible students. Statistical significance (two tailed *z*-test, $p < 0.05$) is highlighted if it occurs.

Table 1: Retention Rate (Retained at BSU)

	N-Calc	R-Calc	Effect Size	*p*-value	*N*
All	78.9%	82.3%	3.4%	0.020	2995
Female	80.8%	84.4%	3.6%	0.181	792
URM	76.6%	82.8%	6.3%	0.107	430
Pell	77.2%	79.6%	2.4%	0.352	1040

The conclusion is that R-Calc shows an improved retention rate (3.4%, $p = 0.020$). The null hypothesis, that R-Calc has no effect on retention is rejected. The effect size is small. This is a modest result and is consistent with the fact that pass rates are better in R-Calc across the same period of time (7.5 points higher for this cohort of students.)

When this picture is restricted to Female students, URM, or Pell-eligible there are similar results. For Female students, the gain is the same as for the full cohort. Pell-eligible students do slightly worse (but still gain in R-Calc). URM gain a decent amount. In all cases the p-values are small but non-significant—we cannot reject the null hypothesis. Nonetheless, the results are still encouraging. In particular, it is clear that retention gains in R-Calc are not obtained as a result of boosting the performance of white males.

3.1.2 STEM Retention Rates – Are STEM majors still in STEM next fall?

While the general retention data is interesting and encouraging, the bigger and perhaps more important story is revealed when examining retention in STEM.

We begin with a look at STEM retention for our full study population, Table 2. The study population drops to 2,352 since we exclude those with no STEM major in their cohort AY and also exclude the tiny number who graduate during their cohort AY. Coincidentally, this results in an almost perfect split into equal numbers for R-Calc and N-Calc. Because it is of some interest where students end up if they are not retained in STEM, we measure three retention outcomes: STEM to STEM (originally STEM major, stayed in STEM); STEM to Non-STEM (originally a STEM major,

Table 2: Retention of STEM Majors -- Headcount

	STEM-to-STEM	STEM-to-Non	Dropped Out	Total
N-Calc	820	111	244	1175
R-Calc	860	108	209	1177
Total	1680	219	453	2352

Table 3: STEM Retention Rates

	N-Calc	R-Calc	Effect Size	p-value
STEM-to-STEM	69.8%	73.1%	3.3%	0.078
STEM-to-Non	9.4%	9.2%	-0.3%	0.821
Dropped Out	20.8%	17.8%	-3.0%	0.064

switched to a Non-STEM major), and Dropped Out (left the university). These are expressed as percentages, along with R-Calc versus N-Calc effects and p-values in Table 3. Things of note in the data from Table 3, depicted in Figure 2 include: The modest retention gain for R-Calc is essentially the same as the general retention gain. However, note that none of the gain comes from keeping students in STEM. All of the gain comes from preventing dropouts. In terms of headcount, it appears that R-Calc keeps about 10 more students per year in STEM, essentially by keeping them in school at all.

3.1.3 STEM Retention Rates – WOMEN and URM

We now consider the retention of women and URM who are STEM majors, where the results begin to show large differences. In Figures 3 and 4 it is clear that the retention gains from R-Calc

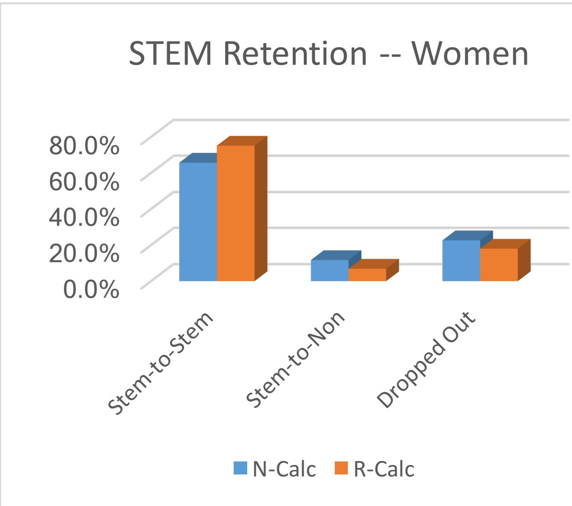

Figure 3: STEM retention - Women

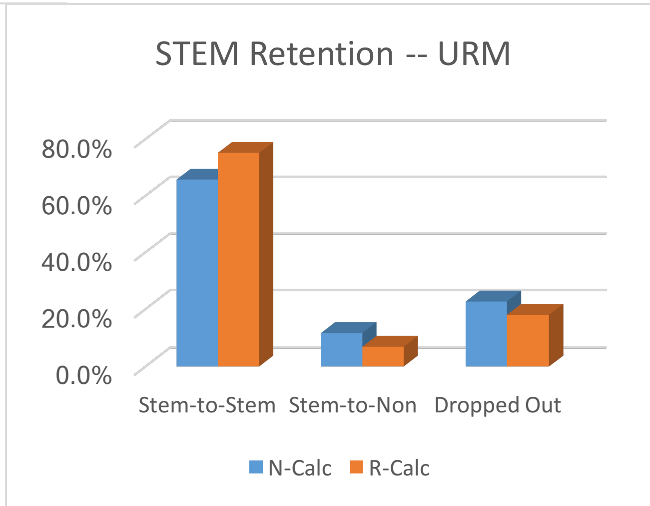

Figure 4: STEM retention - URM

are bigger than for the full cohort. Also, there is a distinct difference in where the students are going. Unlike the general case, there are evident differences in the STEM-to-Non category.

This is more evident in numerical data (Table 4). Both groups show very large gains in retention after R-Calc as compared to N-Calc. For women, the effect size is 9.1% with a p-value of 0.0224. This value is statistically significant; the claim that R-Calc has no effect on retention of Women in STEM at BSU is rejected. For URM, the effect size is 9.4%, with a p-value of 0.0659, which does not quite reach statistical significance.

Table 4: STEM Retention – Women and URM

Women				
	N-Calc	**R-Calc**	**Effect Size**	**p-value**
STEM-to-STEM	63.6%	72.7%	9.1%	0.0224
STEM-to-Non	14.6%	10.4%	-4.2%	0.1392
Dropped Out	21.8%	17.0%	-4.9%	0.1482
URM				
	N-Calc	**R-Calc**	**Effect Size**	**p-value**
STEM-to-STEM	65.7%	75.1%	9.4%	0.0659
STEM-to-Non	11.7%	6.9%	-4.8%	0.1463
Dropped Out	22.6%	18.0%	-4.6%	0.3066

Moreover, unlike the general case, in both of these groups the retention gain is composed of equal parts "stayed in school", and "stayed in STEM". Given that STEM in particular is prone to retention gaps for these populations, this is an important result.

It is also worth looking at this from the point of view of retention gaps. That is, rather than measuring impact on women, or perhaps comparing to a general baseline, consider the direct comparison of retention rates for women versus men. Table 5 shows our data.

Both men and women benefit from retention gains under R-Calc, but gains for women are so large that an 8% gap is almost entirely eliminated.

A similar picture emerges for URM (Table 5). Here the pre-existing gap was smaller, and there is a complication due to international students. Internationals are retained in STEM at considerably higher rates than any other group. In all prior computations, this has had little to no effect (we checked) because the international students are either not part of any computation, or they are relatively evenly split between N-Calc and R-Calc (163 and 153 respectively, which if anything, gives a boost to N-Calc retention rates.) However, the demographic variable that detects URM takes on three values: URM, Non-URM, and International. So, for measuring gaps between URM and other student groups, it matters whether or not International students are included in the non-URM control group. Table 5 shows the results for both cases. As usual, all groups gain. Here, the gains for URM versus either alternative group are so large that a retention gap actually flips.

Table 5: STEM Retention Gap – Women, URM w/o Intn'l, URM w/Intn'l		
Women v Men		
	N-Calc	**R-Calc**
Female	63.6%	72.7%
Male	71.5%	73.2%
Gap	-7.9%	-0.5%
URM v Non-URM, no International		
	N-Calc	**R-Calc**
URM	65.7%	75.1%
Non-URM, no Intn'l	67.9%	70.5%
Gap	-2.2%	4.6%
URM v Non-URM plusInternational		
	N-Calc	**R-Calc**
URM	65.7%	75.1%
Non-URM and Intn'l	70.3%	72.7%
Gap	-4.6%	2.5%

After R-Calc, URM are retained at *higher rates* than either comparison group.

3.1.4 STEM Retention Rates – Pell-Eligible

Unfortunately, there is no such good news for Pell-eligible students, see Table 6. This group still gains from R-Calc, but the gain is slightly less than the gain for all R-Calc students. Also, like the general case, the gain is entirely from fewer dropouts. There is no additional capture of students departing for other majors.

Table 6: STEM Retention – Pell-Eligible				
	N-Calc	**R-Calc**	**Effect Size**	**p-value**
STEM-to-STEM	68.4%	71.2%	2.8%	0.3885
STEM-to-Non	8.0%	8.1%	0.1%	0.9590
Dropped Out	23.6%	20.8%	-2.9%	0.3236

3.2 Success in post-requisite coursework: Course Pair Data

In this section, we revisit an analytic device (Bullock, 2016). We track student performance in courses that are typically taken subsequent to Calculus I. We then compare their success in these post-requisite courses' follow-on courses, depending on which version of Calculus I they used as the prerequisite. In our previous work we studied only the performance in Calculus II, comparing students who took R-Calc against those who took N-Calc. In this paper, we significantly expand the analysis to include a large set of Math, Engineering and Physics post-courses (section 2.2.3) We also include, for additional comparison, performance in the post-course for the cohort of student who did not take Calculus I at BSU. This is intended as primarily descriptive statistical evidence. However, we include significance testing of the difference in post-course pass rates for the R-Calc and N-Calc groups.

The Effect Size and *p*-value are only for the comparison of R-Calc to N-Calc. We do not analyze transfer students; they are provided only for descriptive comparison.

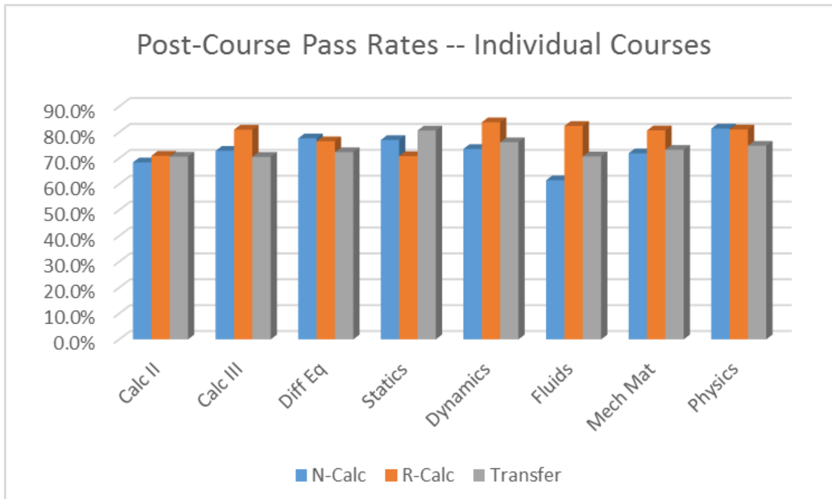

Figure 5: Post-Course Pass Rates

3.2.1 Course-pair data – success in post-requisite courses

Overall

Table 7 and Figure 5 show the pass rate data for the full range of post courses, with students split into N-Calc, R-Calc, and Transfer.[3] Notice that in most courses, R-Calc students outperform N-Calc. Positive effect sizes tend to be larger than negative effects, and have greater statistical significance as denoted by smaller p-values. The only negative effect

Table 7: Post-Course Pass Rates -- Individual Courses

	N-Calc	R-Calc	Transfer	Effect Size	*p*-value	*N*
Calc II	68.4%	70.9%	70.6%	2.5%	0.247	1,983
Calc III	72.8%	81.0%	70.5%	8.1%	0.005	1,055
Diff Eq	77.7%	76.5%	72.3%	-1.2%	0.719	953
Statics	77.0%	70.8%	80.7%	-6.2%	0.104	693
Dynamics	73.5%	83.9%	76.1%	10.3%	0.038	391
Fluids	61.5%	82.5%	70.7%	21.0%	0.001	**352**
Mech Mat	71.9%	80.7%	73.2%	8.8%	0.098	**420**
Physics	81.4%	81.1%	74.8%	-0.3%	0.883	1,462

[3] Footnote: There is a small chance that students in "Transfer" did not actually transfer the prerequisite Calculus I course to BSU, but the number of such instances would be very small.

that calls for attention is perhaps the effect in Statics. This is unsurprising, since statics relies very heavily on good preparation in trigonometry and vector analysis, which are not treated in Calculus I.

The post-course analysis technique was created to study the effect of R-Calc on subsequent Math courses, since there were concerns that content changes in R-Calc could have negative effects on later Math courses. Table 8 presents the result of aggregating all the Math post-courses, and some other aggregates.

There are positive effects in Math and Engineering, in the aggregate. While these are not quite statistically significant, they are still an encouraging result. When all courses are aggregated, the positive effect is statistically significant: We may conclude that R-Calc does a better job of preparing students for subsequent course work, although the effect is fairly small.

Table 8: Post-Course Pass Rates -- Course Types

	N-Calc	R-Calc	Transfer	Effect	*p*-value	*N*
Math	71.8%	74.4%	71.2%	2.6%	0.094	3,991
Engr	72.0%	76.7%	75.5%	4.7%	0.058	1,856
Phys	81.4%	81.1%	74.8%	-0.3%	0.883	1,462
ALL	76.6%	78.7%	75.9%	2.1%	0.040	8,765

3.2.2 Course-Pair Data – Success in post-requisite courses, Female and URM

Figure 6 and Table 9 show the effects on subgroups of female, URM, and Pell-eligible students, with all students included for comparison.

All three groups experience a boost from R-Calc. Consistent with the findings on retention, we see that the gains for URM and women are visibly larger than the general gain for all students. Pell-eligible students, however, actually get less value (but still gain) from R-Calc. Also, interestingly, all three groups perform

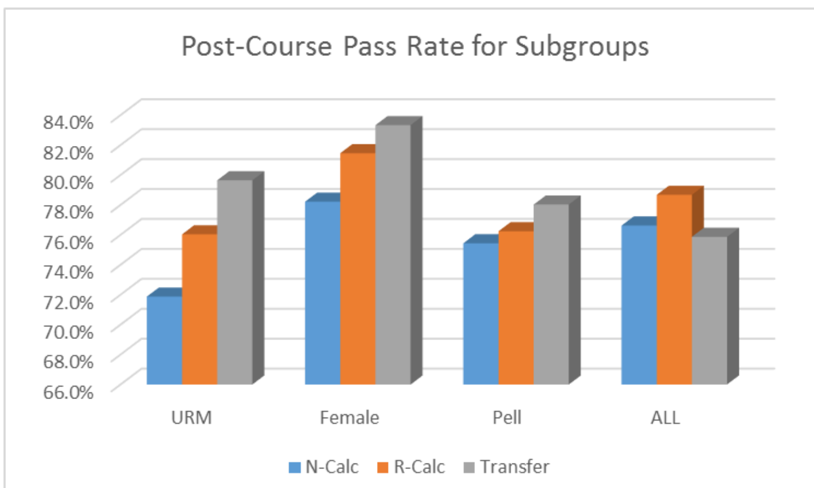

Figure 6: Post-Course Pass Rates for URM, Female, Pell

Table 9: Post-Course Pass Rate for Subgroups

	N-Calc	**R-Calc**	**Transfer**	**Effect**	**p-value**	**N**
URM	71.9%	76.0%	79.6%	4.2%	0.158	1,108
Female	78.2%	81.5%	83.3%	3.2%	0.162	1,496
Pell	75.4%	76.2%	78.0%	0.8%	0.671	2,709
ALL	76.6%	78.7%	75.9%	2.1%	0.040	8,765

much better than transfer students. Both this and the Pell data are revealing and must be considered important targets for future reforms.

4.0 Discussion

The improved retention and performance in certain post-requisite courses that we have seen as a result of R-Calc is now discussed, and is likely influenced by (1) improved grades in the course, (2) increased relevancy of content, (3) active learning, (4) increased self-efficacy, and (5) increased sense of belonging. Other factors may also be relevant.

Improved Grades: The literature on first-year academic success as measured by grade point average shows a clear association with retention; for example, see Whalen (2010) and Herzog (2005). Herzog (2005) also found that after GPA, the strongest predictor of retention was performance in first-year mathematics courses. The role of first course grade in mathematics was also studied by Callahan (2017), who showed that earning a grade of "A" or "B" in mathematics doubled the likelihood of persistence, and that grades earned are more important than the actual level of mathematics course (whether Calculus, Precalculus or College Algebra) taken in the students' first year. Thus, improved retention is expected simply based on the fact that student grades are higher in the R-Calc relative to N-Calc courses. The underlying rationale behind why improved grades increase retention is that students who earn higher grades have a higher sense of self-efficacy. Students with a higher math self-efficacy are more likely to view difficult tasks as something to be mastered than something to be avoided (Bandura, 1977).

Increased Relevancy of Content: The strong focus in R-Calc on providing actual examples from physics, biology, finance or other applied models for students to work with to solve calculus problems is likely to have contributed to increasing student engagement with the mathematics they were learning. Students who don't find value in mathematics learning are likely to disengage; for example, see Allexsaht-Snider and Hart (2001). Ames (1992) reviews key characteristics of tasks that are likely to foster a willingness in students to put forth effort and become actively engaged in learning. These characteristics include tasks that involve variety and diversity, tasks that provide meaningfulness of content, tasks that students perceive they can accomplish with reasonable effort, and tasks that structure student engagement. The pedagogical approaches used in R-Calc very much align with these underlying theoretical principles. Other researchers have also focused effort on improving student learning by means of adding an applications-focus into calculus. For example, Young et al. (2011) developed two, one-credit applications "add-on" courses for students to take alongside "normal" calculus. Their work showed that while the first course, taken with Calculus I, did not have a statistically significant effect, the second 1-credit course, taken with Calculus II, did. Relative to the improved results seen in post-requisite coursework, it is natural that students might more easily recognize when to use calculus in post-requisite courses if they have already seen such examples when they took R-Calc.

Active Learning: It is well known that active learning increases student performance in science, engineering and mathematics. A metaanalysis by Freeman, et al. (2013) of 225 studies, of which 29 were focused on mathematics shows that active learning improves average examination scores by 6%, and students in classes with traditional lecturing are 1.5 times more likely to fail than students in classes with active learning. The metaanalysis shows, based on 15 different independent studies, that a shift to active learning shows an average of approximately 8% decrease in failure rate in the discipline of Mathematics. In Freeman's PNAS report, active learning was defined as learning that "engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. The pedagogical shifts in this work (R-Calc) were all shifts away from "exposition-centered methods" (lecturing) toward constructivist approaches (active learning).

Self-efficacy: Self-efficacy is a critical element that is strongly associated with the literature on retention in STEM disciplines. Bandura's research has shown that high perceived self-efficacy leads students to view difficult tasks as something to be mastered, rather than something to be avoided. (Bandura, 1977). A recent article by Ellis, et al. (2016) shows that women are 1.5 times more likely to leave the STEM pipeline after calculus compared to men and identifies lack of mathematical confidence as a potential culprit. Their paper shows that women start and end the term with significantly lower confidence than men. The approaches taken in our work, which closed the gap in persistence between men and women in STEM, thus may have improved student self-efficacy, although this was not measured.

Belongingness: Dasgupta (2011) describes the importance of the need to belong, and its influence on self-concept. In this work, Dasgupta summarizes how people's behavior and choices are driven by the need to belong and be accepted by others within a community of peers. The need to belong is particularly strong under adversity or stress – and thus "is likely to play an important role in the lives of individuals who belong to historically disadvantaged groups and find themselves in adverse situations where their group is numerically scarce and their abilities cast in doubt, such as high-stakes academic" environments. Dasgupta reviews relevant literature about the imposter syndrome, and more, and goes on to suggest that collectively, "*the experience of being in a numeric minority in high-stakes academic environments where stereotypes are in the air may reduce individuals' self-efficacy or confidence in their own ability, especially in the face of difficulty, even if their actual performance is objectively the same as majority-group members*."

The focus of Dasgupta's 2011 article is to highlight two factors that are likely to contribute to increasing social belonging and to build resilience against stereotypes. These factors are, (1) exposure to ingroup experts, and (2) exposure to peers in high-achievement contexts. In the context of the increased retention of women and URM as a result of R-Calc, "ingroup experts" might refer to a woman enrolled in R-Calc being exposed to other women in R-Calc during the course of the semester in group work. Dasgupta's "stereotype inoculation" model proposes that exposure to ingroup experts and peers in high-stakes achievement contexts functions as a social vaccine that helps inoculate individuals against self-doubt. In this work, we have not focused any effort to date on analyzing the group compositions, which are not regulated, but which rather self-aggregate according to where students place themselves in the classroom. Future work could examine the degree to which students align themselves with ingroup peers.

Belongingness – feeling as though one belongs – cannot be emphasized enough relative to the results we have seen. As summarized by Herzig, 2005, building a sense of "belongingness in mathematics" has been proposed as a critical feature of an equitable K-12 education, where "belongingness refers to the extent to which each student senses that she or he belongs as an important and active participant in all aspects of the learning process." Allexsaht-Snider and Hart (2001) also discuss belongingness – the extent to which each student senses that she or he belongs. The sense that each student feels as though she or he belongs in calculus is critical relative to future decisions made by the student to remain in STEM.

5.0 Summary

Our reform of Calculus has positively affected retention, at least in the year that students encounter Calculus I. Overall retention improved by about 4 percentage points, with gains for women, URM and Pell-eligible students all similar to the general case. Retention in STEM was improved, in general, by about the same amount. We noted especially large gains in STEM retention for women and URM (exceeding 9%). These increases closed the gap in retention of men versus women at this university and resulted in a retention rate for URM that exceeded non-URM students by 4.6%. We attribute these results primarily to the pedagogical shifts that have taken place relative to how the course is taught. These shifts include (1) collaborative work that occurs each day in class, and (2) a strategy of being explicit about the relevancy of calculus by using actual physical situations, data and units in homework problems, in-class work and exams.

Relative to post-requisite coursework, students who experience R-Calc versus N-Calc as the prerequisite to later Math and Engineering course work receive a small, but statistically significant boost in pass rate. The effect is larger in engineering courses, as would be expected given the curriculum in R-Calc. As we have seen elsewhere in the Calculus Transformation project, the gains are even larger for women and URM, but Pell-eligible students are not as well served.

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