Calculus I Course Policy Changes and Impact on Various Demographic Student Group Success

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Introduction

This paper is part of a larger effort to examine the impact of departmental policy changes on the trend in the proportion of students receiving a grade of D, F, or withdrawing from the course (denoted DFW) for introductory calculus at a large research university. A large study of introductory calculus classes across the country found that this course discourages many students from pursuing a degree in STEM (Bressoud 2013) and also “lowers student confidence, enjoyment of mathematics, and desire to continue in a field that requires further mathematics” (Bressoud 2015). Calculus I typically has a high failure rate and has been shown to be a gatekeeper course for STEM degrees (Moore 2005, Suresh 2006, Pyzdrowski et al. 2013). Thus, increasing student success in this course is essential for retaining more STEM majors, which is imperative to sustaining our nation’s global competitiveness (Olson et al. 2012).

Although the total number of students choosing to switch out of STEM fields is discouraging, the outlook for underrepresented minority students is particularly worrisome, with only 20% of these students with an interest in STEM graduating with a STEM degree (Freeman et al. 2014). There is also a gender gap in the amount of STEM degrees conferred, with a higher percentage being awarded to males (65%) than females (35%) in 2013 for all racial and ethnic groups (nces.ed.gov). Thus, the factors impacting student success in Calculus I must be examined with regard to student demographic groups, in hopes of retaining a larger and more diverse group of STEM majors. This paper will provide an initial overview of the impact of Calculus I policy changes on different student demographic groups in order to shed some light on this issue.

Background

Motivated by a recent increase in DFW proportions for Calculus I, Norton et al. (2017) studied the impact of two major departmental policy changes on the trend in DFW proportions from Fall 2002 to Fall 2015. They chose to focus on only the Fall semester since that is the traditional on-track semester, and the time when most freshman are taking calculus. The authors found that these course policy changes had a significant effect on the DFW proportion trend. In particular, students had the lowest DFW proportions during the SCALE-UP (active learning) period of instruction. They also studied the trends in individual D, F, and W proportions and found that the policy changes had the largest impact on the course’s F and W proportions. After further exploring F and W students, they concluded that the midterm average distributions for F and W students were similar during the SCALE-UP period, but students who withdrew had midterm averages that were significantly lower than students who failed when the department’s policy returned to using traditional lecture. These findings give more support to the positive influence of SCALE-UP on reducing DFW proportions.

The prior study did not separate DFW trends by demographic subsets of students. This paper will expand on prior work by examining the impact of Calculus I policy changes on the total DFW proportion as well as individual D, F, and W proportions, separated by student demographic groups. Gender, ethnicity, and major combinations will define these groups.

Summary of Changes

Major changes in the departmental policy took place twice during the span of the study. These changes included instructional method, textbook and online homework software, testing format, addition of new material, placement policies, and passing conditions. We defined three distinct periods that correspond with when the departmental policy changes were implemented. These periods are Traditional Methods (2002-2005), SCALE-UP (2006-2013), and Return to Traditional (2014-2015), which are defined in more detail below.

Traditional Methods (2002-2005)

Traditional lecture was the pedagogical approach used during this time. Additional components of instruction and assessment for this period are described in Table 1 below.

Table 1. Overview of Traditional Methods period course policies

Textbook	Homework	Exam Format	Grading Policy
(2002) *Calculus 4th Edition* (Stewart 2001) (2003-2005) *Calculus 5th Edition* (Stewart 2002)	Variety of daily assignments (short quizzes, assigned problems, short writing assignments, problem presentations, or projects)	Free response	Four exams- 60% Homework-12% Attendance- 3% Final Exam- 25% No additional passing conditions

SCALE-UP (2006-2013)

The SCALE-UP (student centered activities for large enrollment undergraduate programs) instructional model was implemented in Fall 2006. This method encourages active learning and minimizes lecture time in the classroom. Beichner et al. (2007) found that this active learning environment helps increase students' conceptual understanding and supports successful problem solving skills. SCALE-UP classrooms are set-up to support a collaborative learning environment by using large round tables and having two projector screens at both ends of the room. There are approximately 45 students in each class with one instructor and one graduate teaching assistant. After a short lecture (maximum of 20 minutes), students work in groups on learning activities while the instructor and GTA guide group discussions and help students when they get stuck by asking guiding questions that allow them to explain their thinking. Benson et al. (2008) states that the key to SCALE-UP success "is the collective interaction among students, instructor, and teaching assistants."

Additional components of the policy for the SCALE-UP period are summarized in Table 2. This period also consisted of closely coordinated courses sharing common exams and course material, along with the placement policy emphasizing careful class assignment based on students' placement test score.

Table 2. Overview of SCALE-UP period course policies

Textbook	Homework	Exam Format	Grading Policy
(2006-2009) *University Calculus Part One* (Hass, Weir, Thomas 2006) (2010-2013) *Calculus* (Briggs and Cochran 2010)	*MyMathLab* (Pearson) Can include original content by instructors based on common student mistakes	50% Multiple choice 50% Free response	Three exams- 20% each Final exam- 20% Homework-10% Learning activities-10% Passing conditions- 60% exam average or 60% final exam score

Return to Traditional (2014-2015)

In Fall 2014, the departmental policy changed from using SCALE-UP as the instructional method to being determined by individual instructors. The majority of instructors went back to using traditional lecture, with approximately 60% of instructors abandoning the SCALE-UP model in Fall 2014.

Table 3. Overview of Return to Traditional course policies

Textbook	Homework	Exam Format	Grading Policy
Single Variable Calculus: Early Transcendentals 7th Edition (Stewart 2011)	*WebAssign* (Cengage) *ALEKS* (McGraw-Hill Education)	Free response	Three exams-15% each Final exam-25% Homework-10% Learning activities-20%. No additional passing conditions

In addition to the components in Table 3, new material was added to the course during this period. Topics included delta-epsilon, Newton's method, hyperbolic trig functions, proof by induction, and graphing functions with calculators.

A major change in placement occurred during the Return to Traditional period also. Faculty in the math department wrote the previous placement exam. Students now take the new placement exam through the ALEKS software and are given four attempts to score an 80 or higher in order to be placed in the course.

Student Groups

In order to get a better picture of the population of students taking this course, we defined eight student groups based on ethnicity (white/non-white), gender (male/female), and major (STEM/non-STEM) combinations, where STEM includes majors in the College of Engineering and Science. Specifically, this college included all engineering programs, chemistry, computer information systems, computer science, geology, mathematical sciences, and physics. Note that biology is not included in STEM due to college structure at our university. The choice of non-white as an identifier was used because some students had multiple ethnicities listed or none. Thus, we had eight student groups:

1) CFN – STEM Female Non-White
2) CFN – STEM Female White
3) CMN – STEM Male Non-White
4) CMW – STEM Male White
5) NFN – Non-STEM Female Non-White
6) NFW – Non-STEM Female White
7) NMN – Non-STEM Male Non-White
8) NMW – Non-STEM Male White

Table 4 below shows the demographic composition of the course for each year.

Table 4. Demographic composition of courses

Year	CFN	CFW	CMN	CMW	NFN	NFW	NMN	NMW	Total
2002	17	88	53	324	28	108	18	87	723
2003	20	70	82	341	29	88	31	103	764
2004	23	49	95	340	29	100	25	105	766
2005	35	85	61	374	21	113	18	111	818
2006	23	64	80	294	24	114	16	84	699
2007	20	59	72	301	23	106	15	84	680
2008	20	66	62	283	27	130	21	87	696

2009	19	64	35	259	29	157	33	168	764
2010	13	77	46	310	26	181	30	192	875
2011	24	83	34	293	35	175	32	167	843
2012	19	106	50	350	24	215	27	196	987
2013	19	100	53	362	26	125	27	172	884
2014	25	144	67	425	22	135	15	112	945
2015	44	180	111	468	31	120	18	79	1051

Research Questions

1) Are trends and change points in the overall DFW proportion similar across student groups?

2) Are trends and change points in individual D, F, and W proportions similar across student groups?

Results

In order to analyze the trend in total DFW proportions, as well as D, F, and W proportions for the eight demographic groups, we created a series of graphs. The first graph (Figure 1) was used to look at the overall DFW proportion versus year. Linear trend lines were fit within each period. Recall the three periods are Traditional Methods (2002-2005), SCALE-UP (2006-2013), and Return to Traditional (2014-2015). The trends for Figure 1 are summarized in Tables 5 and 6. Table 5 focuses on comparing period trends within each student group, and Table 6 focuses on comparing student group trends within each period. Figures 2, 3, and 4 are similar to Figure 1 but show the D, F, and W proportions respectively. These trends are summarized in Tables 7-12. Tables 7, 9, and 11 focus on comparing period trends within each student group, and Tables 8, 10, and 12 focus on comparing student group trends within each period.

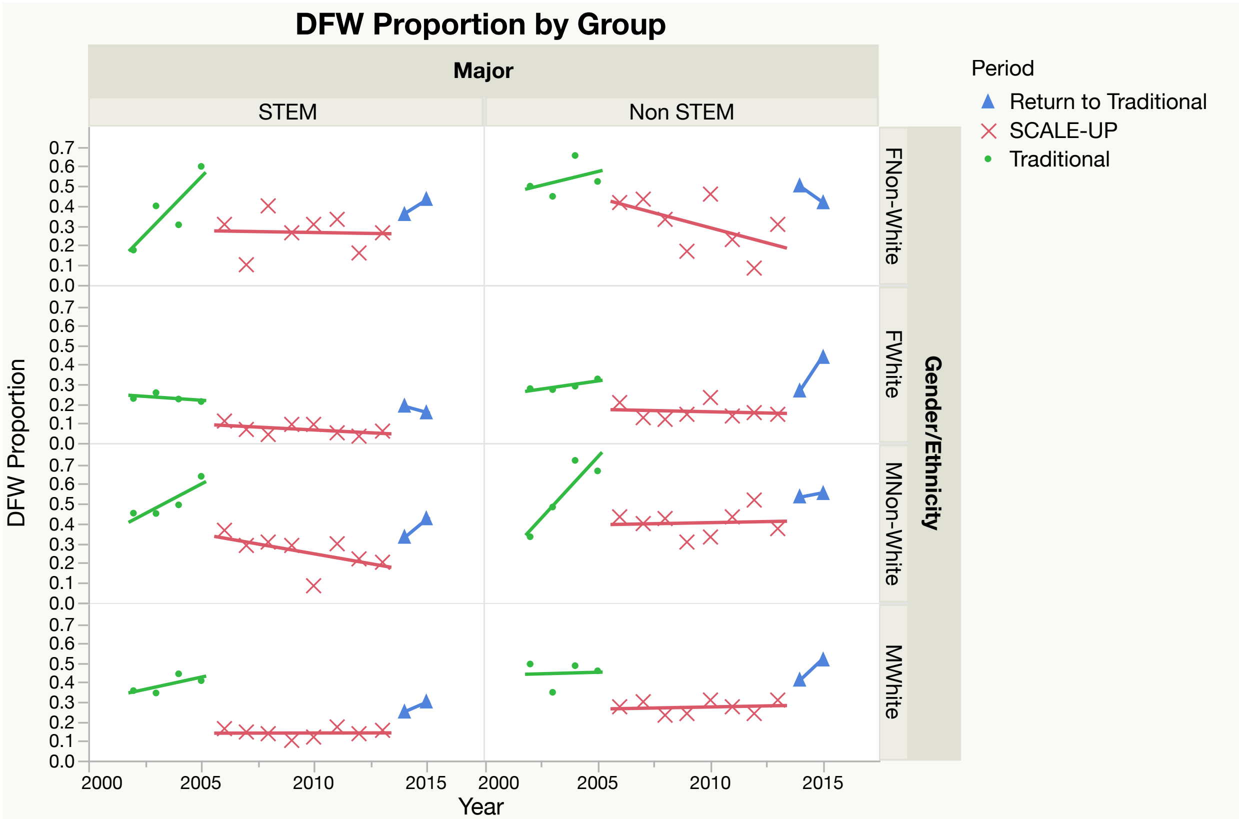

Figure 1. DFW Proportion by Student Group

Table 5. Trends in DFW proportion within student group

Group	DFW proportion trend across the periods
CFN	Rapidly increasing during Traditional, decreased and remained consistent during SCALE-UP, increased after Return to Traditional
CFW	Slightly lower during SCALE-UP. Consistently low regardless of period
CMN	Increasing during Traditional, decreased and continued decreasing during SCALE-UP, increased after Return to Traditional
CMW	Slightly increasing during Traditional, decreased and remained consistent during SCALE-UP, slightly increased after Return to Traditional
NFN	Decreased after SCALE-UP, continued decreasing during SCALE-UP, increased after Return to Traditional
NFW	Slightly lower during SCALE-UP. Consistently low until rapid increase after Return to Traditional.
NMN	Rapidly increasing during Traditional, decreased and remained consistent during SCALE-UP, slightly increased after Return to Traditional
NMW	Decreased and remained consistent during SCALE-UP, increased after Return to Traditional

Table 6. Trends in DFW proportion within period

Period	Overall DFW proportion trend
Traditional	Increasing the most for non-white students
SCALE-UP	Decreased regardless of group
Return to Traditional	Patterns were non-distinct across the different student groups

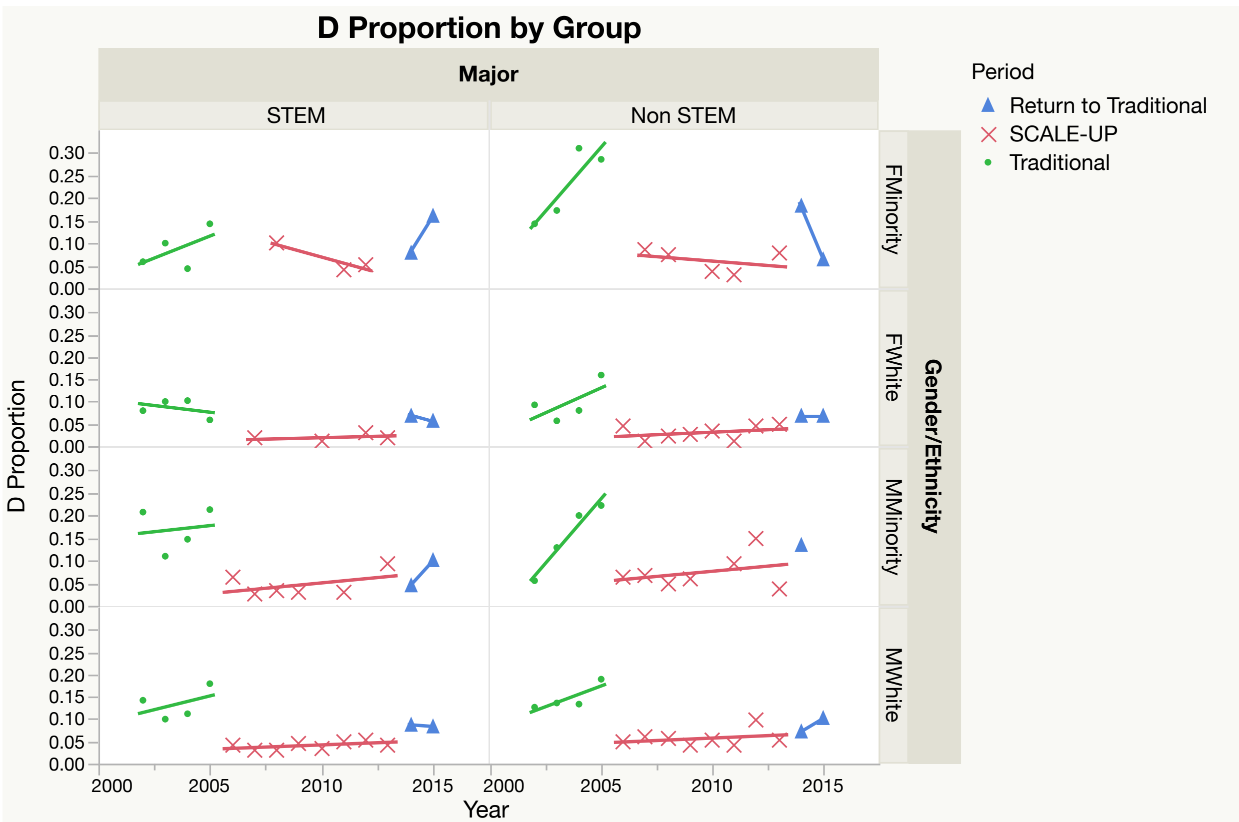

Figure 2. D Proportion by Student Group

Table 7. Trends in D proportion within student group

Group	D proportion trend across the periods
CFN	Increasing during Traditional, decreased and continued decreasing during SCALE-UP, increasing after Return to Traditional
CFW	Decreased after SCALE-UP and remained consistently low
CMN	Slightly increasing during Traditional (large variability), decreased after SCALE-UP, no major change after Return to Traditional
CMW	Increasing during Traditional, decreased after SCALE-UP, remained consistently low
NFN	Rapidly increasing during Traditional, decreased and remained consistent during SCALE-UP, initially increased after Return to Traditional
NFW	Increasing during Traditional, decreased after SCALE-UP, remained consistently low
NMN	Rapidly increasing during Traditional, decreased after SCALE-UP
NMW	Increasing during Traditional, decreased after SCALE-UP, remained consistently low

Table 8. Trends in D proportion within period

Period	Overall D proportion trend
Traditional	Increasing the most for non-STEM students
SCALE-UP	Decreased regardless of group. Largest impact on decreasing D's for non-STEM students
Return to Traditional	Patterns were non-distinct across the different student groups

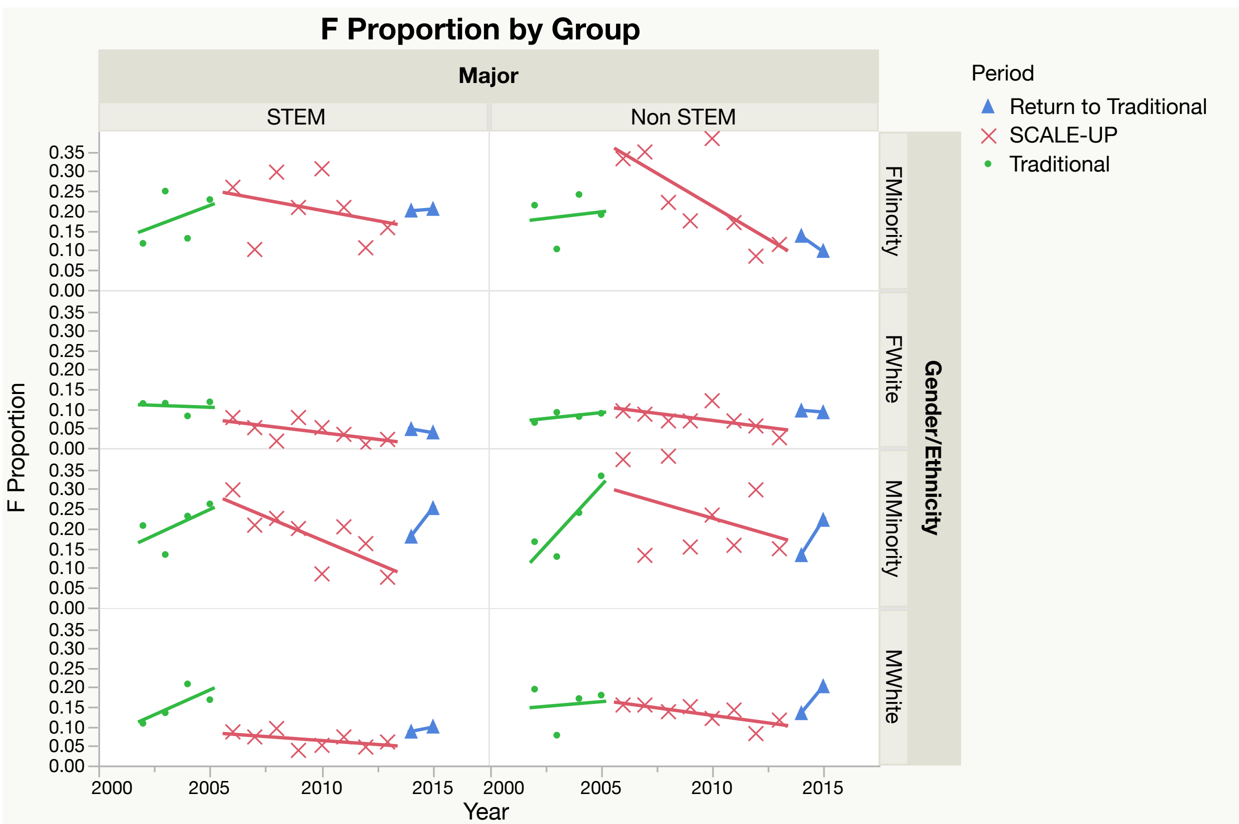

Figure 3. F Proportion by Student Group

Table 9. Trends in F proportion within student group

Group	F proportion trend across the periods
CFN	Increasing during Traditional, decreasing trend during SCALE-UP (large variability), no major change after Return to Traditional
CFW	Consistently low regardless of period
CMN	Increasing during Traditional, rapidly decreasing during SCALE-UP, increased after Return to Traditional
CMW	Increasing during Traditional, decreased after SCALE-UP, no major change after Return to Traditional
NFN	Initially increased after SCALE-UP but then decreasing trend throughout SCALE-UP and Return to Traditional
NFW	Consistently low regardless of period
NMN	Rapidly increasing during Traditional, decreasing during SCALE-UP (large variability), slightly increased after Return to Traditional
NMW	Remained fairly consistent until slight increase after Return to Traditional

Table 10. Trends in F proportion within period

Period	Overall F proportion trend
Traditional	Increasing the most for non-white males
SCALE-UP	Decreasing the most for non-white students
Return to Traditional	Increasing trend for males

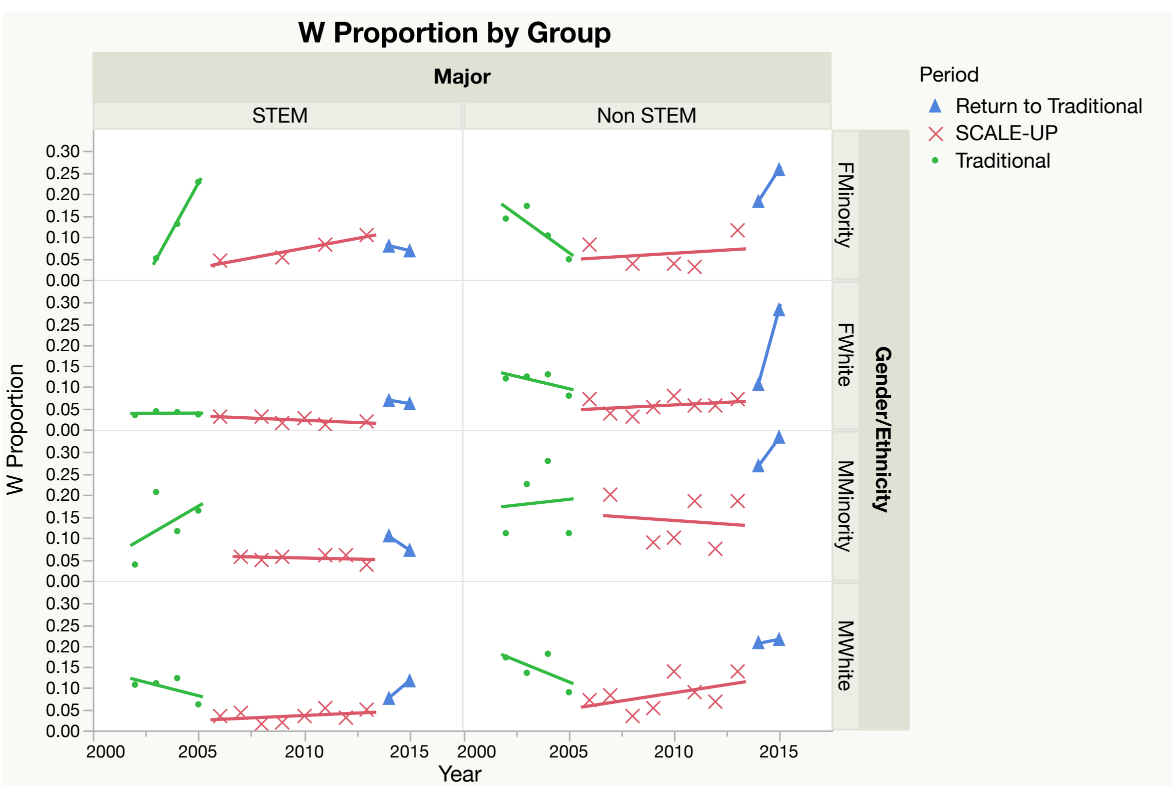

Figure 4. W Proportion by Student Group

Table 11. Trends in W proportion within student group

Group	W proportion trend across the periods
CFN	Rapidly increasing during traditional, decreased after SCALE-UP and slight upward trend throughout the period, no major change after Return to Traditional
CFW	Consistently low regardless of period
CMN	Increasing during traditional, decreased and remained consistent during SCALE-UP, no major change after Return to Traditional
CMW	Slightly decreasing during Traditional, decreased and remained consistent during SCALE-UP, slightly increased after Return to Traditional
NFN	Decreasing during Traditional, trend flattened and remained consistently low during SCALE-UP, increased after Return to Traditional
NFW	Slightly decreasing during Traditional, trend flattened and remained consistently low during SCALE-UP, rapidly increasing after Return to Traditional
NMN	Slightly lower during SCALE-UP than in the Traditional period (large variability), increased after Return to Traditional
NMW	Decreasing during Traditional, decreased after SCALE-UP and slight upward trend throughout the period, increased after Return to Traditional

Table 12. Trends for W proportion within period

Period	Overall W proportion trend
Traditional	Increasing trend for non-white STEM students
SCALE-UP	Appears to have largest impact on reducing W's for non-white STEM students
Return to Traditional	Increasing trend for non-STEM students

Discussion

From the preliminary descriptive analysis of the graphs, we were able to draw the following conclusions. The trends in total DFW, and individual D, F, and W proportions were not consistent across the eight demographic subsets of students. Specifically, white female STEM students typically had the lowest changes in DFW rates corresponding to policy changes, whereas non-white male non-STEM students had the highest changes in DFW rates. In addition to responding differently to the policy changes, the different demographic subsets of students were not equally represented in the course, with white male STEM students being the largest group and non-white female STEM students being the smallest group. Policy changes appeared to have almost no impact on the F rate for white female students, while the policy changes appeared to have the greatest impact on F rates for non-white males. The data also suggested that the change to the SCALE-UP policy had the biggest impact on reducing F's for non-white students. The two policy changes did not appear to change the W rates for white female STEM students. However, the W rates for non-STEM students did appear to change due to policy, specifically by the change from SCALE-UP back to Return to Traditional. Also, the change to SCALE-UP appeared to have the biggest impact on reducing withdrawals for non-white STEM students. Additional formal regression analyses are being developed to confirm these observations.

Conclusion

Even though the DFW proportions were the lowest during the SCALE-UP period regardless of student group, the total DFW proportion was increasing the most for non-white students during the Traditional period, and the proportion of F's decreased the most for non-white students during the SCALE-UP period. These patterns suggest that an active learning environment that includes more interaction between students and the instructor might be even more beneficial for underrepresented minority students, which is consistent with previous literature. Seymour and Hewitt (1997) found that the "straight lecture style" was not the best instructional method for students from any racial or ethnic background, but observed that group learning opportunities "were more sought-after, used, appreciated and missed when unavailable" by women and students of color. A national survey of student engagement showed that gains in achievement from collaborating with peers and interacting with instructors in college courses were higher for students from underrepresented racial and ethnic groups (Wasley 2006). Studies of the SCALE-UP model of instruction have indicated higher success rates compared to traditional lecture especially for women and minority students (Beichner et al. 2007).

Overall, student demographic composition of courses should be taken into consideration when implementing pedagogical reforms, since the impact of the policy changes in this preliminary study differed based on student group. The initial results of this study provide some insight into instructional policies that have a positive impact on reducing DFW proportions for Calculus I. These findings support the larger effort of addressing issues causing introductory calculus to be a barrier to success for many STEM majors.

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