Impact of Course Policy Changes on Calculus I DFW Rates

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Abstract

This paper examines the impact of departmental policy changes on the trend in DFW proportions for introductory calculus at a large research university, where DFW denotes the proportion of students receiving a grade of D, F, or withdrawing from the course. We defined three distinct policy periods: Traditional (2002-2005), Active Learning (SCALE-UP) (2006-2013), and Return to Traditional (2014-2016). Regression analysis showed DFW proportions were increasing during the Traditional period, significantly decreased after the switch to SCALE-UP, remained fairly consistent during the SCALE-UP period, and then significantly increased during Return to Traditional. Individual trends for D, F, and W proportions were also analyzed. The two policy changes had the greatest influence on the trend in F and W proportions. Potential factors that could influence a student to withdraw from the course were examined. Students who withdrew had midterm averages similar to students who failed the course during the SCALE-UP period, but their averages were significantly lower than the F students during the Return to Traditional period.

Introduction

The United States is in great need of more STEM graduates entering the workforce in order to sustain our nation's global competitiveness. The President's Council of Advisors on Science and Technology (PCAST) published the report *Engage to Excel* in 2012, which calls for one million more STEM professionals over the next decade (Olson et al. 2012). In order to achieve this goal, universities would need to increase STEM graduates by 34% annually. They suggest focusing on students in the first two years of college, since research has shown this time to be most critical to retaining STEM majors.

Student success in introductory calculus is imperative to obtaining a degree in any STEM field. During their first year, most STEM majors will enroll in Calculus I and II, which have been shown to be gatekeeper or barrier courses for engineering majors (Moore 2005, Suresh 2006). Barrier courses typically have the highest rate of failures or withdrawals at a university, and students who

aren't successful in these courses tend to switch majors to one that doesn't require the barrier course (Moore 2005, Suresh 2006). Bressoud (2013) particularly emphasizes the importance of Calculus I for STEM retention:

> Each fall, approximately 300,000 college or university students, most of them in their first post-secondary year, take this course. This course is famously perceived to be a filter, discouraging all but the very strongest students from pursuing a career in science or engineering. (p.685)

In addition to being a gatekeeper course, research shows that Calculus I "lowers students' confidence, enjoyment of mathematics, and desire to continue in a field that requires further mathematics," all having a negative impact on retaining STEM majors (Bressoud 2015). Therefore, in order to graduate more STEM professionals, we must start with examining the factors contributing to student success in Calculus I.

The impetus for this study was the university's concern with a recent increase in DFW proportions for introductory Calculus I (MATH 1060). Two major departmental policy changes for MATH 1060 took place in 2006 and then again in 2014 that impacted the trend in DFW rates. To better understand the implications of these policy changes, we decided to create a dataset of student grades spanning 2002-2016. These changes were a combination of instructional method, addition of new material, textbook and online homework software, testing format, placement policies, and passing conditions for the course. In order to study the effect of these changes on DFW proportions, we chose to focus solely on introductory Calculus I courses (MATH 1060) taken in the fall semester. MATH 1060 is usually the first math course STEM majors take at the university. Thus, these students are typically around

the same age and haven't transferred pre-requisite course credit from another institution. Also, the fall semester for MATH 1060 is the traditional "on-track" semester for the course and the time most freshmen take calculus (Pyzdrowski et al. 2012). The spring semester adds many complexities such as students re-taking the course or students who started in a pre-calculus course (MATH 1050).

Summary of Changes

We defined three distinct periods that coincide with when the departmental policy changes were implemented. These periods are Traditional Methods (2002-2005), SCALE-UP (2006-2013), and Return to Traditional (2014-2016), which are defined below.

Traditional Methods (2002-2005)

The pedagogical approach used during this time was exactly what the section title suggests, "traditional lecture". This specifically involved the components described in Table 1.

The homework during this period was not completed online, but consisted of daily assignments such as short quizzes, assigned problems, short writing assignments, problem presentations, or projects. Attendance in class was mandatory, with three percent of the final course average being dedicated to class attendance. The number of points a student was awarded for this category depended on the number of unexcused absences they acquired: 0-1 (3 points), 2-4 (2 points), 5-6 (1 point), and greater than 6 unexcused absences resulted in 0 points. The first exam included a pre-calculus basic skills portion that was worth 25% of the overall test score. The final exam consisted of a calculator and a non-calculator portion. Once students

Textbook	Homework	Exam Format	Grading Policy
(2002) *Calculus 4th Edition* (Stewart 2001) (2003-2005) *Calculus 5th Edition* (Stewart 2002)	Variety of daily assignments	Free response	Four exams- 60% Homework-12% Attendance- 3% Final Exam- 25%

Table 1. Overview of Traditional Methods period course policies

turned in the first part of the exam, they were allowed to use a calculator to complete the second part. There were no additional passing conditions to the grading policy stated above.

SCALE-UP (2006-2013)

A new instructional method for MATH 1060 was first implemented in Fall 2006 called SCALE-UP (student centered activities for large enrollment undergraduate programs). The SCALE-UP approach supports student collaboration and active learning by minimizing lecture time and focusing on hands-on problem solving in the classroom. Active learning means that students are engaged in the learning process, rather than passively receiving information from a traditional lecture (Prince 2004). SCALE-UP classrooms usually consist of around 45 students with one instructor and one teaching assistant per room. Students sit at large round tables with three groups of three students each per table. This format encourages collaboration and helps develop a community of learners (Benson et al. 2008). Lectures are kept to less than 20 minutes, and students spend the remainder of class time working in groups on learning activities, which incorporate problems that apply the new concepts just presented. The instructor and TA guide group discussions and assist students in answering their own questions by having students explain their thinking, rather than just providing them with the correct answer. This active learning environment has been shown to increase students' conceptual understanding and support successful problem solving skills (Beichner et al. 2007).

Prior to the implementation of the SCALE-UP model in Fall 2006, all instructors were required to take part in a training workshop the week before the semester started. This workshop consisted of mock lessons that demonstrated both the content of the course as well as the new pedagogical approach. The instructors participated in the learning activity portion of the example lessons and discussed details about how to best assess the group work. Pertinent literature about the SCALE-UP model was also presented and discussed among the instructors during the training workshop.

From Fall 2006 to Fall 2013, this instructional method was coupled with closely coordinated courses sharing common exams, course material, online homework, and grading policies with the goal of reducing variability among sections of MATH 1060. The online homework software *MyMathLab* can include original content by instructors based on common student mistakes. Fisher and Lipson (1986) found that "pedagogical methods that systematically address common student errors produce significant gains in student learning." In addition to the grading policy below (Table 2), the passing conditions for the course stated students must pass the final exam or have a final passing average on the tests and final exam to receive a passing grade in the course. Also during this period, the placement policy emphasized careful class assignment based on students' placement test score.

Return to Traditional (2014-2016)

In Fall 2014, another major departmental policy change for MATH 1060 took place. The instructional

method changed from SCALE-UP to being determined by each individual instructor, with the majority of instructors returning to using traditional lecture. During this period, approximately 40% of instructors continued using the SCALE-UP model in Fall 2014 and only around 30% used SCALE-UP in Fall 2015.

The homework software changed to WebAssign along with ALEKS, an online pre-calculus review, and the original content with common student mistakes was no longer available to students with this new software. The previous passing conditions were removed in 2014 with the added condition that an ALEKS score of less than 85 would result in lowering a student's final course grade by one full letter grade. In Fall 2016, the passing condition of at least a 60% exam average or final exam score to pass the course was reinstated. New material was also 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.

Another major change in the placement policy occurred during the Return to Traditional period. Mathematics faculty developed the previous placement exam, which consisted of 50 multiple-choice questions and was scored on a scale from 1-6. The first half of the exam was an algebra skills test, and students were required to pass this section in order to receive a score of 4, 5, or 6 on the placement exam. Students could only take this exam one time but were given the opportunity to take the Algebra Exemption Test (AET) on the first night of classes if they were not satisfied with their placement exam score. A pass on the AET was equivalent to a placement exam score of 3. Along with the placement exam, students were required to take a basic skills test (BST) on the first day of the course. If a student scored a 3 or 4 on the placement exam, they were required to earn a sufficient BST score to be able to stay in the class. The new placement exam is administered to students through the ALEKS software. Students are given four attempts on the new placement exam and must score an 80 or higher to be placed in the course. The BST is still given but is now only used for advisement purposes.

Research Questions

The major policy changes and the varying DFW proportions in MATH 1060 led to the following research questions for this study:

1) What is the actual trend in mean DFW proportions over time?
2) Are there significant change points in the DFW proportion trend associated with department policies being implemented or changed?
3) Are trends and change points similar for D, F, and W proportions?
4) What factors might influence students to withdraw from the course?

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)	50% Multiple choice 50% Free response	Three exams- 20% each Final exam- 20% Homework-10% Learning activities-10%

Table 2. Overview of SCALE-UP period 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	(2014) Three exams-15% each Homework-10% Learning activities-20% Final exam-25% (2015) Three exams- 20% each Learning activities- 10% Final exam- 30% (2016) Three exams- 20% each Learning activities- 10% Homework- 10% Final exam- 20%

Table 3. Overview of Return to Traditional course policies

Results

In order to get a better picture of the trends in grades during the entire span of the study, we first developed four bar charts. Figure 1 is the total enrollment and Figures 2-4 show the number of D's, F's, and W's, respectively. We began to see trends in the numbers of D, F, and W grades associated with our three study periods. We noticed grades were changing consistently with our periods, but as is obvious from Figure 1, the total enrollment was also changing. Therefore, we decided to re-express Figures 2-4 in proportions of D, F, and W grades.

The first graph (Figure 5) was used to determine the changes in 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 (2014-2016). Figures 6, 7, and 8 are similar to Figure 5 except that the figures show the D, F, and W proportions, respectively.

In Figure 5, the overall DFW proportion slope and mean appears to change between Traditional Methods and SCALE-UP, and then change again between SCALE-UP and Return to Traditional. Figure 6 shows that the mean D proportion decreases from the Traditional Methods to SCALE-UP, but the change in the mean D proportion between SCALE-UP and Return to Traditional is not as dramatic. Figure 7 shows that the mean F proportion decreases slightly during the change from the Traditional Methods to SCALE-UP, continues decreasing during SCALE-UP, and then increases in the Return to Traditional period. Figure 8 shows that the mean W proportion decreases during the change from Traditional Methods to SCALE-UP, however the slope in W proportions slightly increases during the SCALE-UP period. The mean W proportion increases during the Return to Traditional Period, but the slope does not change much from the SCALE-UP period.

In addition to the descriptive analysis of the graphs, formal regression analysis was used to statistically compare slopes and means at the points where policies changed. A statistical model was developed for each grade proportion and the overall DFW proportion that included terms for year, period, and the year by period interaction. Assumptions concerning distributions, variances, and influential data points were also checked. The model was estimated and then F-tests of terms in the model were used to address the specific questions about the trend in means and slopes. This analysis revealed that slopes for Traditional Methods and SCALE-UP are significantly different (p=0.0273). The mean DFW proportion for Traditional Methods is significantly different than the mean proportion for SCALE-UP in 2006 (p <0.0001) and 2007 (p< 0.0001), with the estimate of the difference in means being 26.14%. Slopes for Return to Traditional and SCALE-UP are not significantly different (p=0.6336). However, the mean DFW proportion for Return to Traditional is significantly different than mean proportion for
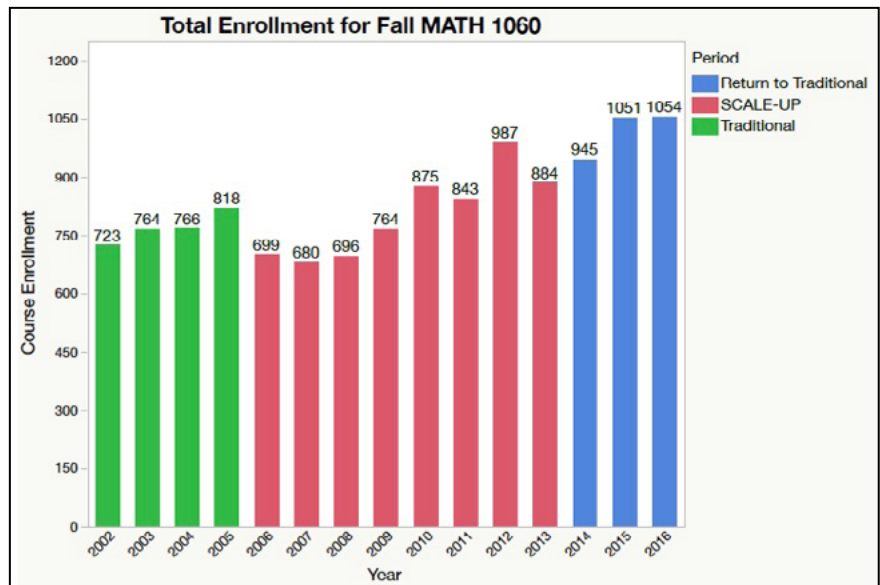

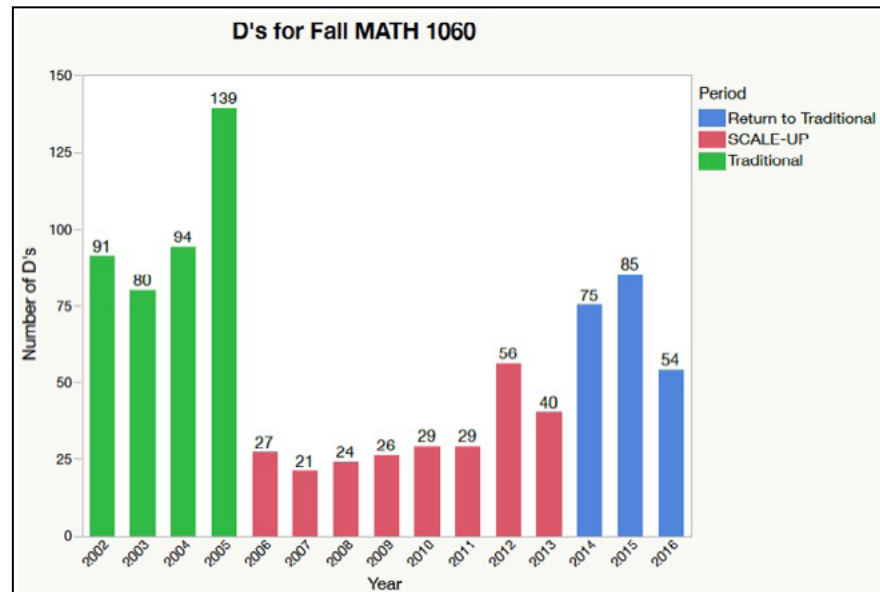**Figure 1. Total Enrollment for Fall MATH 1060**

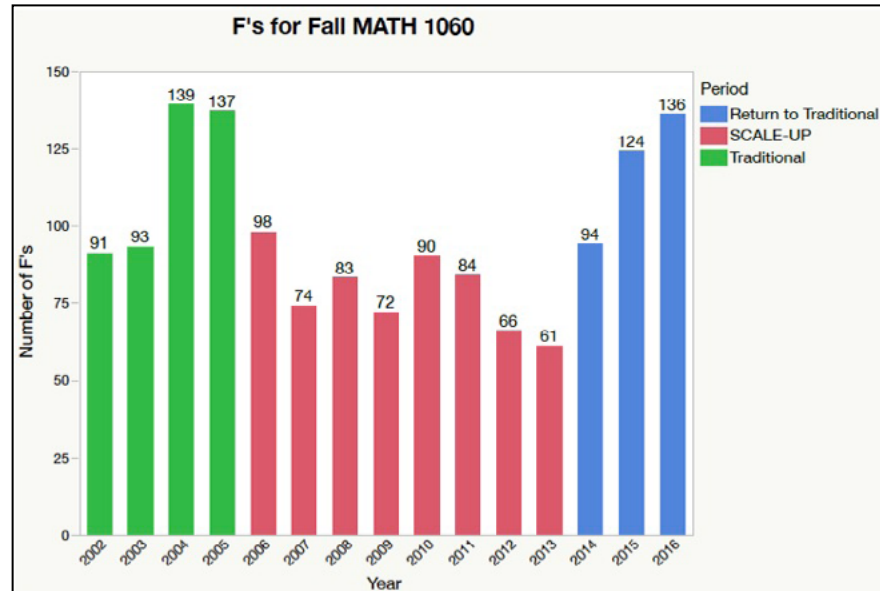**Figure 2. Number of D's for Fall MATH 1060**

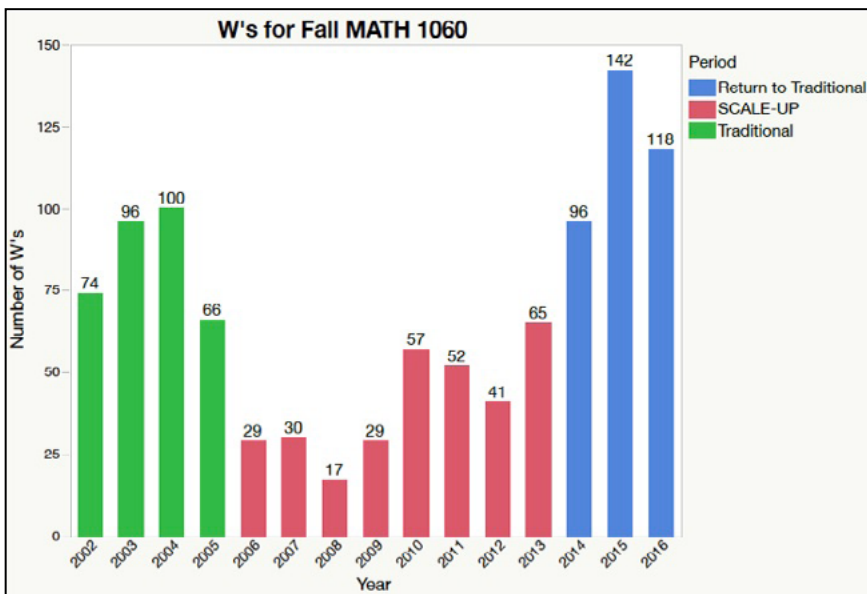
Figure 3. Number of F's for Fall MATH 1060

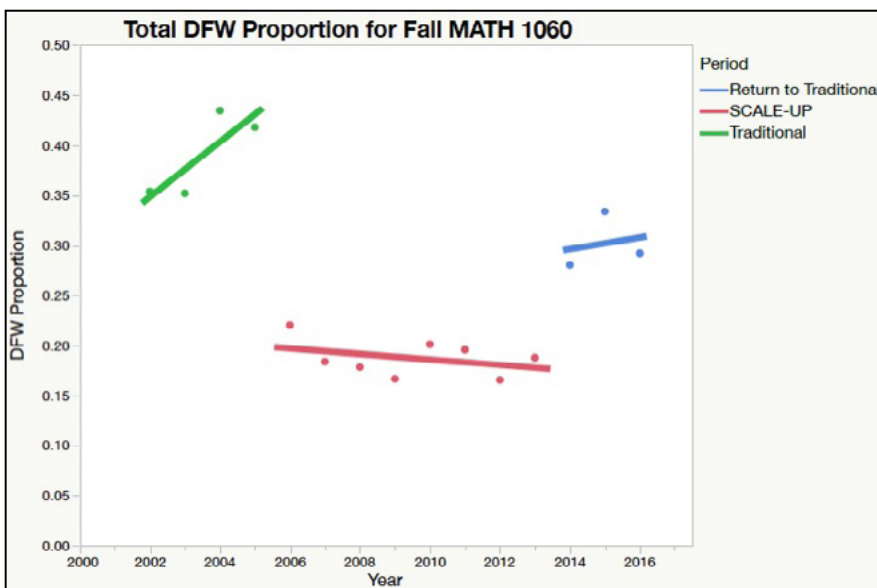Figure 4. Number of W's for Fall MATH 1060

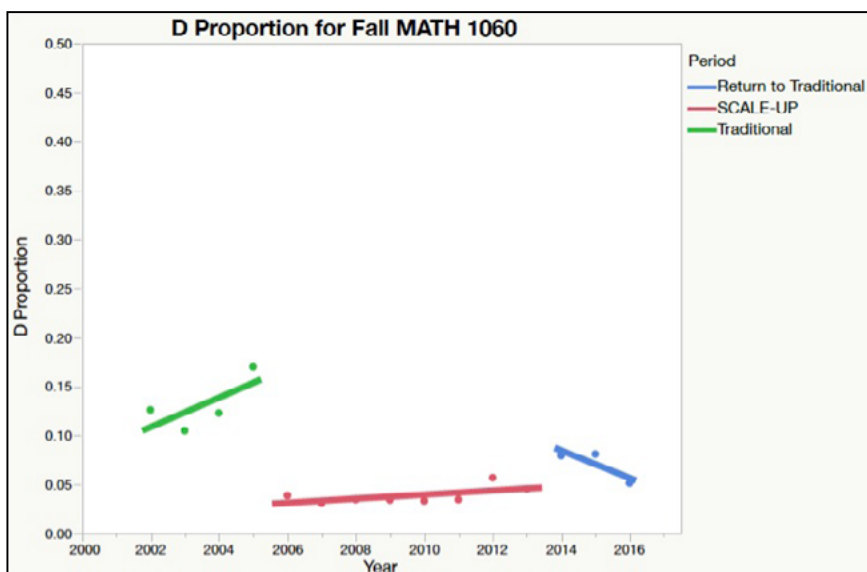Figure 5. Total DFW Proportion for MATH 1060

Figure 6. D Proportion for MATH 1060

SCALE-UP in 2014 ($p=0.0024$) and 2015 ($p=0.0008$). The estimated difference in mean proportions is 12.15%. Overall, DFW proportions were rapidly increasing before the SCALE-UP period and drastically decreased after the policy changes made in Fall 2006. The DFW proportions remained fairly consistent during this period, and then significantly increased after the second round of policy changes that took place in Fall 2014.

Next, the total DFW proportions were separated into D's, F's, and W's, and we analyzed the trends for each individual proportion. Throughout the literature regarding student success, these proportions are consistently reported together, and the individual proportions for each grade are not usually considered. The problem with introductory calculus is commonly indicated to be a high DFW proportion or a high rate of failures and withdrawals (Edge and Friedberg 1984, Suresh 2006, Benson et al. 2010, Pyzdrowski et al. 2012). Bressoud (2013) states "the grades DFW are grouped because they are all indicators that the students were not prepared to continue to any course with Calculus I as a prerequisite" (p.694). While this is certainly true, it is also important to consider the proportions of D's, F's, and W's separately since different factors could lead students to withdraw rather than receive a D or F in the course.

First, we looked at the proportions of D's. Slopes for the yearly changes in D proportions for Traditional Methods and SCALE-UP are not significantly different ($p=0.0757$). The mean D proportion for Traditional Methods is significantly different than mean D proportion for SCALE-UP in 2006 ($p=0.0001$) and 2007 ($p=0.0001$). The estimate of the difference in mean D proportions is 13.72%. Slopes for Return to Traditional and SCALE-UP are not significantly different ($p=0.1361$). The mean D proportion was slightly higher ($p=0.0512$) immediately after Return to Traditional, but by 2015 was not different than SCALE-UP ($p=0.1968$). Overall, the first round of policy changes made in Fall 2006 had a positive impact on reducing the proportion of D's, while no significant changes were seen after the Fall 2014 policy changes.

Next, we analyzed the trend in the proportion of F's for the course. Slopes for the yearly changes in F proportions for Traditional Methods and SCALE-UP are significantly different ($p=0.0023$). The mean F proportion for Traditional Methods is significantly different than the mean proportion for SCALE-UP in 2006 ($p=0.0089$) and 2007 ($p=0.0041$). The estimate for the difference in mean F proportions is 6.36%. Slopes for Return to Traditional and SCALE-UP are significantly different ($p=0.0413$). The mean F proportion for Return to Traditional is significantly different than the mean proportion for SCALE-UP in 2014 ($p=0.0348$) and 2015 ($p=0.0019$). The estimate of the difference in mean F proportions is 6.50%.

Finally we examined withdrawal proportions. Slopes for Traditional Methods and SCALE-UP are not significantly different ($p=0.2755$). The mean W proportion for Tra-
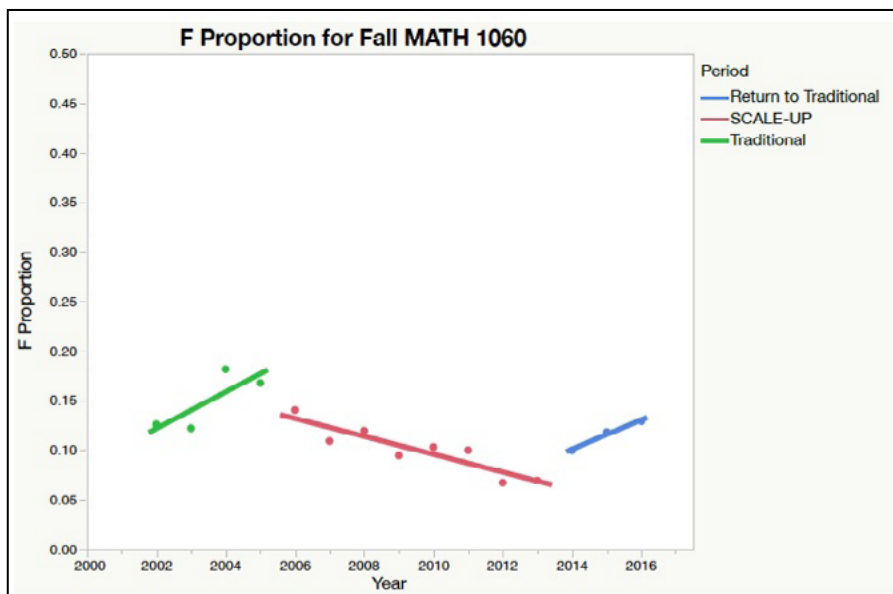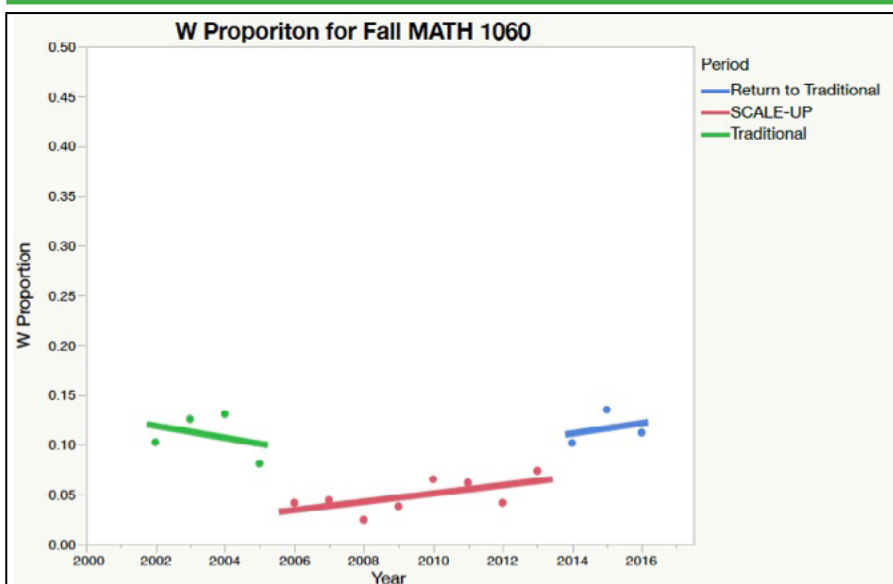
Figure 7. F Proportion for MATH 1060
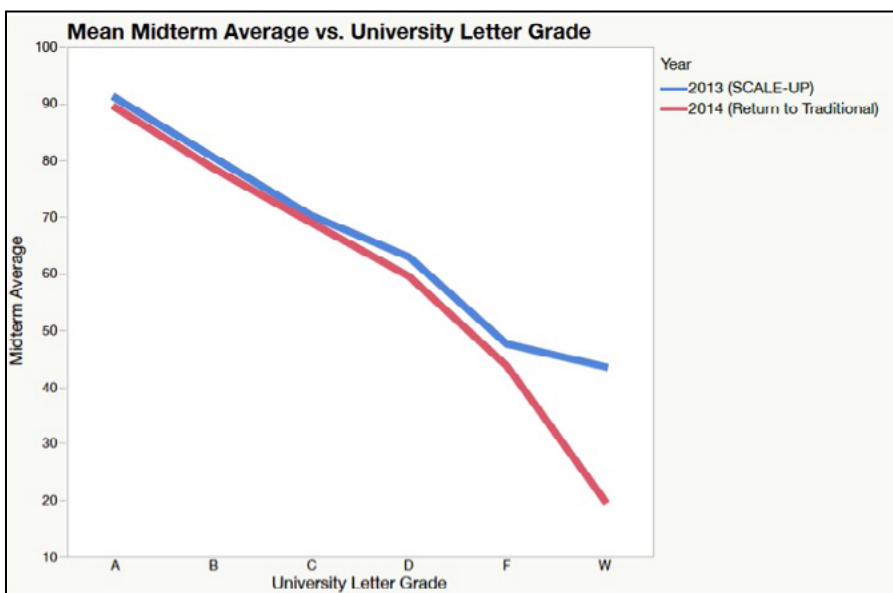

Figure 8. W Proportion for MATH 1060

Figure 9. Mean Midterm Average vs. Final Letter Grade

ditional Methods is significantly different than the mean proportion for SCALE-UP in 2006 (p=0.0424), but not in 2007 (p=0.1489). The estimate for the difference in mean W proportions is 6.06%. Slopes for Return to Traditional and SCALE-UP are not significantly different (p=0.9415). The mean W proportion for Return to Traditional was slightly different than the mean proportion for SCALE-UP in 2014 (p=0.0821), and also in 2015 (p=0.0542). The estimate of the difference in mean W proportions is 4.50%.

Overall, the two policy changes appeared to be more associated with F and W proportions than with D proportions. This led us to further investigate failures and withdrawals. We proceeded by examining factors that could impact a student's decision to withdraw from the course. A search of the literature showed very few articles regarding individual course withdrawals, with most focusing on college retention rates. There is a large amount of research concerning overall withdraw from higher education, but the literature on individual course withdrawal is less developed (Michalski 2011). According to Dunwoody and Frank (1995), course withdrawal rates have been ignored, and there is no information in the literature regarding how course withdrawal impacts the chance of a student completing their degree. Also, Hall (2003) found that "very little research has been conducted and published regarding the reasons a student withdraws from a course," even though course withdrawal negatively impacts students' progress towards graduation (p. 2). They further state that "this will be particularly true if the course is the first in a sequence of required courses," which is certainly the case for introductory calculus for STEM majors (Hall et al. 2003, p. 2). Thus, studying reasons why students withdraw from this course is crucial to ensuring more STEM students successfully complete their degree.

Despite the lack of information in the literature regarding students' reasoning behind course withdrawal, two studies have been conducted that shed some light on the issue. Hall (2003) found that the main reason students withdrew from a class was that they were doing poorly in the course. Also, Dunwoody and Frank (1995) identified the top reason students indicated for withdrawing as "I was not happy with my grade". We hypothesized that many withdrawing students were actually achieving a B, C, or D letter grade, but wanted or needed a higher grade (A, B, or C, respectively) and chose to withdraw instead of achieving the lower grade. In order to investigate this, we looked at the mean of students' midterm averages for each of the final letter grades (Figure 9). This was done for two periods, SCALE-UP and Return to Traditional. If our hypothesis was correct, we would expect the mean of the midterm averages for W students to be somewhat similar to the B, C, and D final letter grades.

From Figure 9, we can see that our hypothesis was not correct. To formally test our hypothesis, first we used ANOVA to determine that the mean midterm averages

differed based on final letter grade for both 2013 (p < 0.0001) and 2014 (p < 0.0001). Fisher's LSD was then used to compare the mean midterm average for W students to all other final grades. The mean of the midterm averages for the W students was significantly lower than the B, C, and D final grades (p-values < 0.0001), and in fact looks most similar to the midterm average of students who received an F for their final grade in the course. Also, the mean midterm averages for F and W students were not significantly different in Fall 2013. After the policy changes made in Fall 2014, the mean midterm average for W students was significantly lower than B, C, D, and F students (p-values < 0.0001). Therefore, students were making the correct decision to withdraw since they were indeed failing the class, not just unhappy with a low but passing grade like we hypothesized. Additionally, the mean midterm average for W students is significantly lower (p <0.0001) for the Return to Traditional period (mean=19.98) than for the prior SCALE-UP period (mean=43.55). Another important observation is that the mean midterm averages for the A, B, and C grades remained fairly stable after the policy changes. Thus, the change in instructional approach from SCALE-UP back to traditional methods has specifically impacted the struggling students and resulted in even lower midterm averages for students who chose to withdraw.

Conclusion

This research was motivated by a recent increase in DFW proportions for introductory college calculus. In order to gain insight into factors contributing to this increase, the relationship of two major departmental policy changes to the trend in DFW proportions were explored. Individual D, F, and W trends were also studied. By analyzing the trend in DFW proportions from Fall 2002-Fall 2016, we found that the two policy changes were strongly related to the overall DFW rate, with students being the most successful (in terms of the DFW proportions being lower) during the SCALE-UP period of instruction. Another important finding was that the policy changes for MATH 1060 had the greatest influence on the course's F and W proportions.

After examining students' midterm averages to further understand the F and W proportions, we discovered that the students who withdrew had averages similar to students who failed the course during the SCALE-UP period. However, the midterm averages for W students were significantly lower than the F students when the math department's policy returned to using traditional pedagogical methods, giving more evidence to support the positive influence of SCALE-UP on reducing DFW proportions.

It is important to emphasize that the possible cause of the change in DFW rates were the policy changes in general. It is an unfortunate shortcoming of the data available for this study that a plethora of factors were all changed simultaneously. Therefore, it is impossible to attribute the change in DFW rates to any specific factors or even order the factors as to their contribution to the changes that occurred. An important addition to this study would be to identify a university where course policies were changed with the specific purpose of conducting a statistical factorial study suitable for pinpointing specific factors involved in DFW rate changes.

Another important note is that DFW trends were not separated across demographic subsets of students, as defined by gender, ethnicity, and major combinations. In addition, the different demographic groups of students were not equally represented in the course. How the DFW trends change due to policies, separated by demographic subsets, will be explored in future work.

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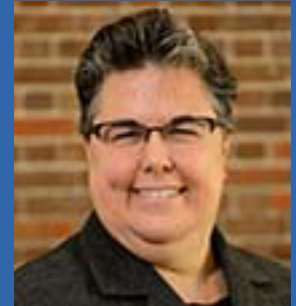
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