Impact of course policy changes on calculus II DFW rates

Paran R. Norton, Karen A. High
Engineering and Science Education Department
Clemson University
Clemson, SC, USA
pfisch@clemson.edu

William C. Bridges
Mathematical Sciences Department
Clemson University

***Abstract*— This paper examines the impact of departmental policy changes on the trend in DFW proportions for Calculus II at a large research university. Calculus I and II have been shown to be barrier courses for STEM majors, so increasing student success in these courses is imperative to retaining more students in STEM fields. A study was conducted to investigate how the DFW proportions for Calculus II changed in response to the policy changes. The data spanned Spring 2002- Fall 2016, and major changes in policy took place twice during this time. The policy changes were a combination of instructional method, textbook and online homework software, grading policies and passing conditions for the course. Three periods corresponding to the policy changes were defined: Pre-SCALE-UP (2002-2006), Active Learning (SCALE-UP) (2007-2013), and Post-SCALE-UP (2014-2016). The findings suggested that the second round of policy changes made in Calculus II had a larger impact on the mean DFW proportion than the first round of policy changes. The policy changes impacted individual D, F, and W proportions for the fall semester, while only the W proportion for the spring semester seemed to be affected, specifically by the Post-SCALE-UP changes.**

Keywords— calculus success, DFW, active learning

I. Introduction

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 [1, 2]. 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 [1, 2]. Thus, increasing student success in Calculus I and II is essential to retaining more students in STEM fields.

In a prior study, Norton, Bridges, and High (2017) examined the impact of two major departmental policy changes on the trend in DFW proportions for Calculus I from Fall 2002 to Fall 2016, where DFW denotes the proportion of students receiving a grade of D, F, or withdrawing from the course [3]. The policy changes were a combination of instructional method, textbook and online homework software, addition of new material, placement policies and passing conditions for the course. Three distinct periods corresponding to the policy changes were defined: Traditional Methods (2002-2005), Active Learning (SCALE-UP) (2006-2013), and Return to Traditional (2014-2016). Results of the Calculus I study indicated the overall DFW proportions were increasing during the Traditional period, significantly decreasing after the switch to SCALE-UP, remained fairly consistent during the SCALE-UP period, and then significantly increasing during the Return to Traditional period.

The Calculus I study also investigated the changes in individual D, F, and W proportions and found that the policy changes had the largest impact on 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. Finally, the Calculus I study also revealed that white female STEM students typically had the lowest changes in DFW proportions corresponding to policy changes, whereas non-white male non-STEM students had the highest changes in DFW proportions. In addition, the change to SCALE-UP had the largest impact on reducing F's for non-white students [4].

The results from the Calculus I (MATH 1060) study led to consideration of a similar study of Calculus II (MATH 1080), as success in this course is also imperative. As part of a larger effort to understand issues causing introductory calculus to be a gatekeeper course, this work in progress paper will give an initial overview of the impact of policy changes on the total DFW proportions in Calculus II, as well as the individual D, F, and W proportions.

II. Summary of Changes

In order to study the effect of policy changes on the DFW proportion trend for MATH 1080, we created a dataset of student grades spanning Spring 2002- Fall 2016. As in MATH 1060, the changes included instructional method, textbook and online homework software, testing format, and passing

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conditions for the course. We defined three policy periods based on the combined policy changes implemented by the department. These periods are Pre-SCALE-UP (2002-2006), SCALE-UP (2007-2013), and Post-SCALE-UP (2014-2016), which are summarized below.

A. Pre-SCALE-UP (2002-2006)

The instructional method during this time was determined by each individual instructor. Additional course policies are described below.

a) Textbook: The textbook used throughout this period was Calculus 5th Edition by Stewart.

b) Homework: The homework was determined by individual instructors and included short quizzes, assigned problems, short writing assignments, problem presentations, or projects. In Fall 2005 only, the homework was completed online through Blackboard.

c) Exam Format: The exams during this period focused on free response questions.

d) Grading Policy:

- Fall 2002- Spring 2005: 4 exams (60%), Homework (12%), Attendance (3%), Final Exam (25%)
- Fall 2005: 4 exams (60%), Basic Skills Test (1%), Attendance and Online Homework (5%), Daily Grade (assigned by individual instructors) (9%), Final Examination (25%).
- Fall 2006: 4 exams (60%), Homework (15%), Final Exam (25%). The passing condition of at least a 60% weighted exam average or final exam score was added this year.

B. SCALE-UP (2007-2013)

The student centered activities for large enrollment undergraduate programs instructional model (SCALE-UP) was implemented for MATH 1080 in Spring 2007. This method encourages active learning and has been shown to help increase students' conceptual understanding and problem solving skills [5]. Benson et al. (2008) states that the key to SCALE-UP's success "is the collective interaction among students, instructor, and teaching assistants" [6]. Additional course policies for this period are described below.

a) Textbook: From Fall 2007-Spring 2010, the textbook used was University Calculus Part One, 1st Edition by Hass, Weir, and Thomas. Calculus Part One (Single Variable), 1st Edition by Briggs and Cochran was used for the remainder of this period.

b) Homework: The homework was completed online through the software My Math Lab.

c) Exam Format: The exams during this period were a mixture of free response and multiple choice questions.

d) Grading Policy:

- Fall 2007- Spring 2009: 4 exams (50%), Learning Activities (12.5%), Homework (12.5%), Final Exam (25%)
- Spring 2010- Fall 2013: 3 exams (60%), Homework (10%), Learning Activities (10%) Final Exam (20%), Passing conditions were a 60% weighted exam average or final exam score.

C. Post-SCALE-UP (2014-2016)

In Spring 2014, the instructional method for MATH 1080 changed from SCALE-UP to being determined by each individual instructor. Additional course policies for this period are described below.

a) Textbook: In Spring 2014, the textbook used was Calculus Part One (Single Variable), 1st Edition by Briggs and Cochran. From Fall 2014- Fall 2016, Single Variable Calculus: Early Transcendentals, 7th Edition by James Stewart was used.

b) Homework: The homework was completed online through the software My Math Lab in Spring 2014. In Fall 2014, the homework software changed to Web Assign. There was no departmental online homework requirement in Spring and Fall 2015.

c) Exam Format: The exam format was not consistent during this period. In Spring 2014- Spring 2015, exams were free response only. In Fall 2015, exams 1 and 2 were free response only, and exam 3 and the final exam included multiple choice and free repsonse questions. The exams for the remainder of this period were a combination of multiple choice and free repsonse.

d) Grading Policy:

- Spring 2014: 3 exams (60%), Homework (10%), Daily Grade (average of quizzes and assignments determined by individual instructor) (10%), Final Exam (20%). Passing conditions were a 60% weighted exam average or final exam score.
- Fall 2014: 3 exams (60%), Homework (5%), Daily Grade (10%), Final Exam (25%).
- Spring 2015: 3 exams (60%), Section Grade (consists of weekly quizzes or other work determined by section instructor) (15%), Final Exam (25%).
- Fall 2015: 3 exams (60%), Section Grade (consists of weekly quizzes or other work determined by section instructor) (10%), Final Exam (30%).
- Spring 2016- Fall 2016: 3 exams (60%), Homework (5%), Daily Grade (average of quizzes and assignments determined by individual instructor) (10%), Final Exam (25%). Passing conditions were a 60% weighted exam average or final exam score.

III. RESEARCH QUESTIONS

The major policy changes in MATH 1080 led to the following research questions: (1) What is the actual trend in mean DFW proportions over time? (2) Is the mean overall DFW proportion significantly different between the three policy periods? (3) Are the mean proportions for individual D, F, and W grades significantly different between the three policy periods?

IV. PREMILIMARY RESULTS AND DISCUSSION

The first step in analyzing the trend in total DFW proportions for MATH 1080 and address the respective hypotheses was to visualize the data set. Figure 1 shows the total course enrollment for each semester. Figures 2 and 3 were used to see the overall DFW proportion versus year for Fall MATH 1080 and Spring MATH 1080, respectively. Recall the three periods are Pre-SCALE-UP (2002-2006), SCALE-UP (2007-2013), and Post-SCALE-UP (2014-2016).

The next step was to compare the mean DFW proportions among the three periods. Analysis of Variance (ANOVA) was chosen as the statistical methodology to compare the means, and the data met the assumptions necessary for ANOVA results to be valid. The results indicate a difference in the mean DFW proportions among the three periods for Fall MATH 1080 ($p < 0.0001$) and Spring MATH 1080 ($p = 0.0361$).

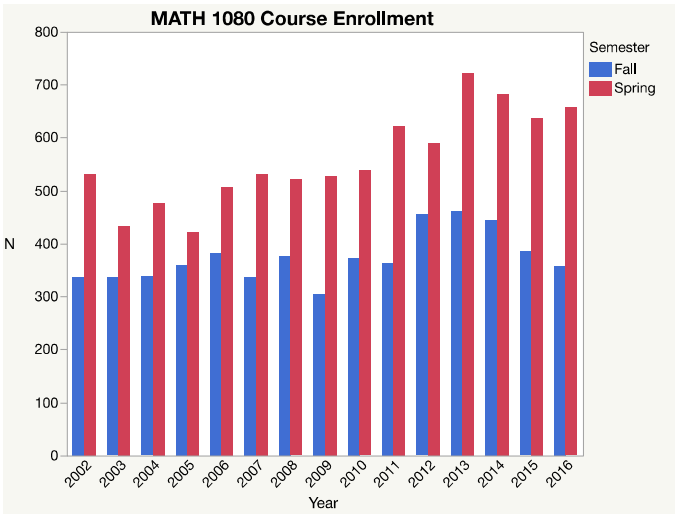

Fig. 1. MATH 1080 Course Enrollment

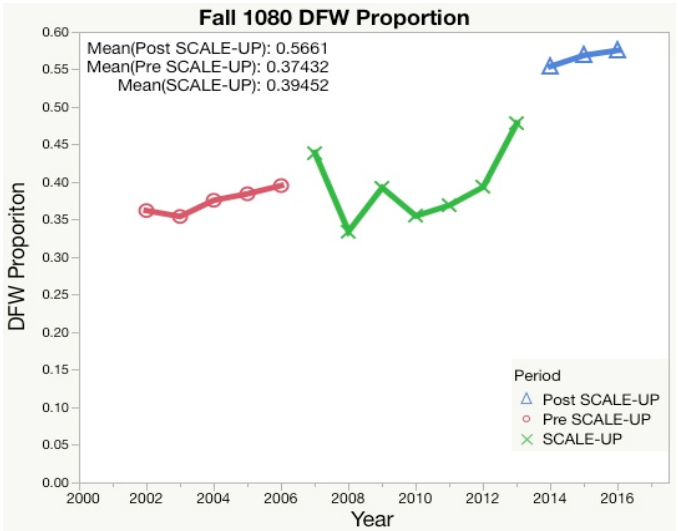

Fig. 2. Fall MATH 1080 DFW Proportion

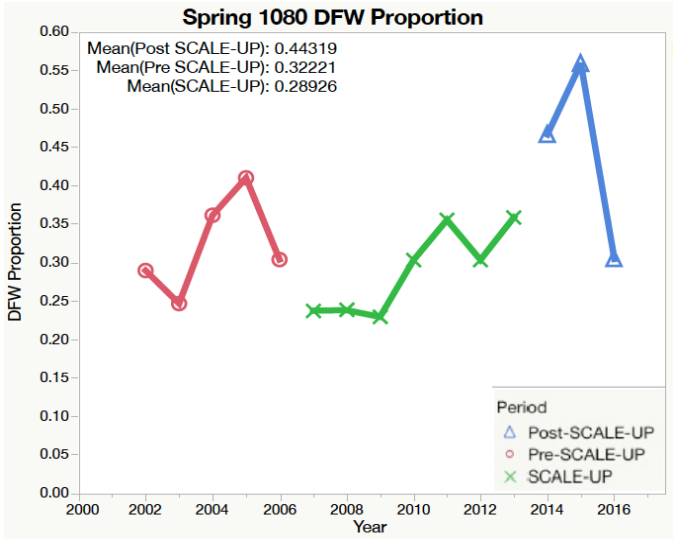

Fig. 3. Spring MATH 1080 DFW Proportion

Given the differences among the three period means, the next step was to perform all pairwise comparisons between the period means. Student's t-test was chosen as the statistical methodology to perform the pairwise comparisons, and the data met the assumptions necessary for Student's t-test results to be valid. These results are shown in Tables I and II. For Fall MATH 1080, the mean DFW proportion for the Post-SCALE-UP period is significantly different than both the Pre- SCALE-UP and SCALE-UP periods ($p < 0.0001$). Also, for Spring MATH 1080, the mean DFW proportion for the Post-SCALE-UP period is significantly different than both the Pre-SCALE-UP ($p=0.0482$) and SCALE-UP periods ($p=0.0119$). No significant differences in mean DFW proportions were found between the Pre-SCALE-UP and SCALE-UP periods for either semester.

In addition to analyzing the overall DFW proportion, we were also interested in examining changes in individual D, F, and W proportions for MATH 1080. For Fall MATH 1080, the ANOVA results show a significant difference in mean D proportions ($p=0.0045$), F proportions ($p=0.0008$), and W proportions ($p=0.0117$) between the three periods. For Spring

TABLE I. FALL 1080 DFW PROPORTION T-TESTS

Comparison	Difference	St.Error	Lower CL	Upper CL	p-value
Post SCALE-UP -Pre SCALE-UP	0.1918	0.0269	0.1333	0.2503	<0.0001
Post SCALE-UP - SCALE-UP	0.1716	0.0254	0.1163	0.2269	<0.0001
SCALE-UP- Pre SCALE-UP	0.0202	0.0215	-0.0267	0.0671	0.3666

TABLE II. SPRING 1080 DFW PROPORTION T-TESTS

Comparison	Difference	St.Error	Lower CL	Upper CL	p-value
Post SCALE-UP - SCALE-UP	0.1539	0.0519	0.0407	0.2671	0.0119
Post SCALE-UP -Pre SCALE-UP	0.1210	0.0549	0.0011	0.2408	0.0482
Pre SCALE-UP-SCALE-UP	0.0329	0.0441	-0.0631	0.1290	0.4693

MATH 1080, there is a significant difference in mean W proportions between the three periods (p=0.0145), but no significant differences were found for D proportions (p=0.1082) or F proportions (p=0.1074). The results for all pairwise mean comparisons for D, F, and W proportions for Fall MATH 1080 are shown in Tables III, IV, and V. The results for all pairwise mean comparisons for W proportions for Spring MATH 1080 are given in Table VI.

For Fall MATH 1080, the mean D proportion for the Pre-SCALE-UP period is significantly different than both the SCALE-UP (p=0.0014) and Post-SCALE-UP (p=0.0232) periods. Overall, the first round of policy changes had a positive impact on reducing the proportion of D's, while no significant changes in D's were seen after that. All pairwise mean comparisons between the three periods were significant for the F proportion, which suggests both policy changes had an impact on F's. The mean W proportion for the Post-SCALE-UP period is significantly different than the Pre-SCALE-UP (p=0.0056) and SCALE-UP (p=0.0070) periods, suggesting the second round of policy changes had a large impact on W's.

TABLE III. FALL 1080 D PROPORTION T-TESTS

Comparison	Difference	St.Error	Lower CL	Upper CL	p-value
Pre SCALE-UP - SCALE-UP	0.0464	0.0113	0.0218	0.0706	0.0014
Pre SCALE-UP-Post SCALE-UP	0.0365	0.0140	0.0059	0.0671	0.0232
Post SCALEUP-SCALE-UP	0.0099	0.0132	-0.0190	0.0388	0.4699

TABLE IV. FALL 1080 F PROPORTION T-TESTS

Comparison	Difference	St.Error	Lower CL	Upper CL	p-value
Post SCALE-UP -Pre SCALE-UP	0.1216	0.0236	0.0702	0.1729	0.0002
Post SCALE-UP - SCALE-UP	0.0646	0.0223	0.0160	0.1131	0.0134
SCALE-UP-Pre SCALE-UP	0.0569	0.0189	0.0158	0.0981	0.0108

TABLE V. FALL 1080 W PROPORTION T-TESTS

Comparison	Difference	St.Error	Lower CL	Upper CL	p-value
Post SCALE-UP -Pre SCALE-UP	0.1067	0.0316	0.0377	0.1758	0.0056
Post SCALE-UP -SCALE-UP	0.0971	0.0299	0.0319	0.1623	0.0070
SCALE-UP-Pre SCALE-UP	0.0096	0.0254	-0.0457	0.0649	0.7114

TABLE VI. SPRING 1080 W PROPORTION T-TESTS

Comparison	Difference	St.Error	Lower CL	Upper CL	p-value
Post SCALE-UP -SCALE-UP	0.1530	0.0436	0.0579	0.2481	0.0043
Post SCALE-UP -Pre SCALE-UP	0.1097	0.0462	0.0090	0.2103	0.0351
SCALE-UP-Pre SCALE-UP	0.0433	0.0370	-0.0373	0.1240	0.2645

Since no significant differences in mean D or F proportions were found between the three policy periods for Spring MATH 1080, pairwise mean comparisons were only conducted for the W proportion. The mean W proportion for the Post-SCALE-UP period is significantly different than the Pre-SCALE-UP (p=0.0351) and SCALE-UP (p=0.0043) periods. These results suggest the second round of policy changes had the largest impact on increasing the proportion of W's for Spring MATH 1080.

V. CONCLUSIONS AND FUTURE WORK

The initial results of this preliminary study provide some insight into instructional policies that have an impact on DFW proportions for Calculus II. Overall, the second round of policy changes made in MATH 1080 had a larger impact on the mean DFW proportions for both the spring and fall semesters than the first round of policy changes. The policy changes impacted individual D, F, and W proportions for Fall MATH 1080, while only the W proportion for Spring MATH 1080 seemed to be affected, specifically by the Post-SCALE-UP changes. Thus, future work will include examining factors contributing to students withdrawing from the course. In addition, since the prior study for MATH 1060 revealed differing trends based on student demographic groups, the impact of course policy changes on DFW trends for MATH 1080, separated by demographic subsets, will be explored.

REFERENCES

[1] J. Moore, "Undergraduate mathematics achievement in the emerging ethnic engineers programme". International Journal of Mathematical Education in Science and Technology. vol.36. pp. 529–537, 2005.

[2] R. Suresh, "The relationship between barrier courses and persistence in engineering." Journal of College Student Retention: Research, Theory and Practice, vol.8. pp. 215–239, 2006.

[3] P. Norton, W. Bridges, and K. High, "Impact of course policy changes on calculus I DFW rates" unpublished.

[4] P. Norton, K. High, and W. Bridges, "Calculus I course policy changes and impact on various demographic student group success". 2017 American Society for Engineering Education. ASEE Annual Conference Proceedings, June 2017, Columbus. Ohio.

[5] R. J. Beichner, J. M Saul, D. S. Abbott, J. J., Morse, D. Deardorff, R. J. Allain, and J. S. Risley,"The student-centered activities for large enrollment undergraduate programs (SCALE-UP) project". Research-Based Reform of University Physics, vol.1, pp. 2–39, 2007.

[6] L. Benson, W. Moss, S. Schiff., S. Biggers, M. Orr, and M. Ohland, "Special session-enhancing student learning using SCALE-UP format," In 2008 IEEE. 38th Annual Frontiers in Education Conference, pp. T2J-1, October 2008.