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Relative Rates of Success of Students in Calculus I

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Abstract

Abstract

Students that enroll in Math 1220, Calculus 1, can be categorized into two groups after completion of the course; those that are successful and able to proceed to the next course by earning a grade of "C" or better (pass) and those that are not successful and unable to proceed to the next course by earning below a "C" (fail). The Mathematics Association of America (MAA) has reported the national average of unsuccessful Calculus 1 students to be 25%. At the conclusion of the spring 2015 semester at Western Michigan University (WMU), the rate was approximately 40%. Institutional data was examined with the intent to discover any trends in the students that were unsuccessful. These trends can be found in how students are placed into Calculus 1, specific measurements of progression throughout the course, and time gap in knowledge between a students' previous mathematics course and Calculus 1. From the data, there are clear indicators of success and failure for students enrolled in Calculus 1. Instructors teaching this course should be aware of these early warning signs of failure so that they can be proactive and work with the identified at-risk students. The intent of this is for the success rate of students to increase, and the fail rate to decrease.

Table of Contents

Introduction

At Western Michigan University, several courses contain students who are struggling with persistence and progression issues. Many students are enrolling in Math 1220, Calculus 1, and because of their experience in the course are not persisting and progressing through the calculus sequence. According to the Mathematics Association of America, Calculus 1 occupies a unique position as a gateway course to science, technology, engineering, and mathematics (STEM) degrees. Almost all STEM majors need to take at least the first course in a traditional Calculus sequence. For many students, this first course in the Calculus sequence is either an obstacle that they cannot overcome or a discouragement to continue in their current degree path. Many students may have felt that they were strong in mathematics in high school, but after their first college course in Calculus, they become discouraged in their abilities to continue from the unexpected rigor of the course.

At the end of a semester, students can be categorized as either students that successfully complete the class they enrolled in with a grade of "C" or better to be able to move on to the next course, designated as a pass, and those who earn below a "C" and are not able to move onto the next course, designated as a fail. Based on information gathered from the fall 2005 semester to the spring 2015 semester, there has been an annual increase for students that are unsuccessful. As of the spring 2015 semester, approximately 40% of students that enrolled in MATH 1220 were unsuccessful in completing the course and being able to move on to the next course. When this is compared to the national average of 25% as reported by the Mathematics Association of America (MAA), it is clear that something is happening.

Through my thesis work, I hope to explore trends in the relative rates of success based on student characteristics in order to investigate the rates of students that fail and/or do not earn at least a "C" in Calculus 1 at Western Michigan University as well as to determine if early warning signs exists for instructors to use to identify potential unsuccessful students. These trends may be characteristic of, but are not limited to gender, racial background, prior knowledge of mathematics, and placement into MATH 1220. The intention of identifying such trends would be that the current and future instructors of MATH 1220 could use the results in their classrooms. Using this information, changes can be made to the way the course is taught which in turn can help more students be successful. The Western Michigan University Department of Mathematics, the College of Arts and Sciences, and the university as a whole may also be able to use the results to reduce the number of students that are unsuccessful and do not complete specific courses for credit.

Methods of Investigation

For the purposes of the investigation, institutional data[1] was pulled for the following semesters; Spring 2014, Fall 2014, Spring 2015, Fall 2015, Spring 2016, and Fall 2016. The summer semesters were not included due to low enrollment. Records were separated into two groups, fall and spring semesters of 2014 and 2015, and fall and spring semesters of 2016. Starting in the spring of 2016, Calculus 1 was coordinated. Therefore, starting spring 2016, it can be assumed that a grade earned from one instructor is equivalent to the same grade from another instructor due to the common assessments and grading rubrics used to assess students. Additionally, specific data points were available from the 2016 semesters that were not a part of

[1] Data was pulled by thesis chair and scrubbed of all personal identifying information before given to me.

the course in previous semesters. These included initial assessments taken during the first few weeks of school, two mastery exams given at different points in the semester, and the requirement that all Calculus 1 students have a midterm grade released. All of these pieces of information were analyzed to identify trends in how students scored in each of these metrics, and whether or not they were successful. The 2014 and 2015 data was then used to track trends in different characteristics of the student population, such as gender and ethnicity.

In this thesis, the following areas are investigated. First, how students are being placed into Calculus 1. Placement methods include successful completion of Pre-Calculus, ACT scores, and an advisor override. Secondly, the initial assessment score, scores on the first and second mastery exams, and midterm grades measured student's progression through the course. Each of these metrics was then compared to the student's final course grade to determine if the metrics could be used to predict success and/or failure in the course. Finally, the time gap in knowledge was analyzed, which was how long students waited between taking their previous math class and enrolling in Calculus 1.

General Results for Student Demographics

To begin, it is important to understand the big picture, and general numbers for the success of students that were enrolled in Calculus 1. It is important to note that enrollment for females is very low compared to enrollment for males. Therefore, conclusions cannot be drawn for females as statistical results fluctuate easily with a low sample size. Below is a table showing data for both spring and fall semesters of 2014, 2015, and 2016. Since new coordination of Calculus 1 began spring 2016, the data is color coded to show the change of instruction for

pre/post coordination. In addition, a weighted average was used to calculate the overall percentage of students that failed.

Figure 1: Gender fail rates

Gender	% Female Fail	% Male Fail	% Overall Fail
Spring 2014	18	38	33.4
Fall 2014	51	42	44.34
Spring 2015	37	43	41.5
Fall 2015	23	38	34.25
Spring 2016	**16**	**36**	**32.4**
Fall 2016	**3**	**15**	**12.48**

One can see that failure rates spiked and remained high during the 2014 and 2015 years. When coordination began in spring 2016, those numbers started to decrease. This is a direct result of the new coordination that was implemented. Since female numbers fluctuated more due to low numbers, the data for females is not conclusive; however, it is pertinent to note that in five of the six semesters shown in Figure 1, female fail rates were lower than male fail rates.

Besides gender, it is also important to look at ethnicity of the student population taking Calculus 1. Below are tables showing data for both spring and fall semesters of 2014, 2015, and 2016. Since new coordination of Calculus 1 began spring 2016, the data is color coded to show the change of instruction for pre/post coordination.

Figure 2: Ethnicity fail rates

Asian	# Pass	# Fail	% Fail
Spring 2014	5	1	17
Fall 2014	3	2	40
Spring 2015	1	0	0
Fall 2015	9	2	18
Spring 2016	2	0	0
Fall 2016	2	2	50

2+ Races	# Pass	# Fail	% Fail
Spring 2014	6	2	25
Fall 2014	3	3	50
Spring 2015	1	4	80
Fall 2015	4	3	43
Spring 2016	7	2	22
Fall 2016	0	0	0

Black	# Pass	# Fail	% Fail
Spring 2014	7	4	36
Fall 2014	4	8	66
Spring 2015	7	9	56
Fall 2015	3	10	77
Spring 2016	8	4	33
Fall 2016	3	2	40

International	# Pass	# Fail	% Fail
Spring 2014	11	2	15
Fall 2014	6	2	25
Spring 2015	4	4	50
Fall 2015	7	3	30
Spring 2016	12	0	0
Fall 2016	11	1	8

Hispanic	# Pass	# Fail	% Fail
Spring 2014	4	0	0
Fall 2014	3	4	57
Spring 2015	7	2	22
Fall 2015	4	3	43
Spring 2016	6	3	33
Fall 2016	2	3	60

White	# Pass	# Fail	% Fail
Spring 2014	63	39	38
Fall 2014	73	54	43
Spring 2015	68	45	40
Fall 2015	94	42	31
Spring 2016	57	36	39
Fall 2016	83	11	12

From this data, one can see that high fail rates exist within underrepresented minority groups as well as majority groups. Since new coordination began, there has been a decrease in White students that fail; however, the underrepresented minority groups have seen little change in their failure rates. This shows that all students are struggling to be successful in Calculus 1; however, success issues have begun to trend towards minority students in recent semesters.

Placement

Math 1180

Beginning with placement, successful completion of Pre-Calculus (MATH 1180) at Western Michigan University or with equivalent transfer credit (TCR) from another accredited institution is how the majority of students were placed into Calculus. Of the 137 students enrolled in Calculus 1 in the spring 2016, 102 (74%) of students were placed based on their MATH 1180 scores, and of the 154 for fall 2016, 78 (51%) were placed based on their MATH 1180 scores. This is the dominant method of placement used to determine if students are ready for Calculus 1 at Western Michigan University. Beginning with spring 2016 and then fall 2016 semesters, the following tables and charts show information on students' success in the course.

Figure 3: Spring 2016 Female placements via MATH 1180

1180 Score	Pass	Fail
A	2	0
BA	3	0
B	5	0
CB	3	0
C	0	4
TCR (transfer Credit)	3	0

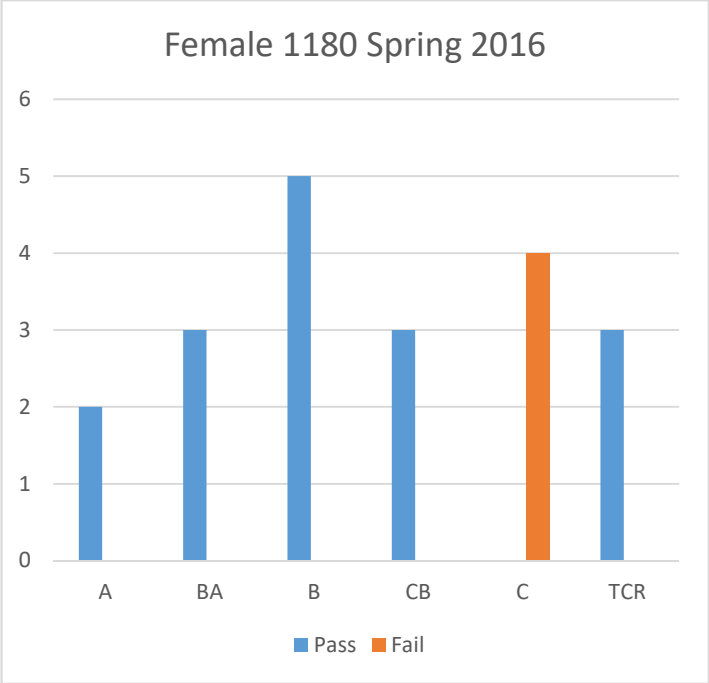


Figure 4: Spring 2016 Male placements via MATH 1180

1180 Score	Pass	Fail
A	3	2
BA	14	0
B	15	6
CB	11	6
C	7	11
TCR	3	4

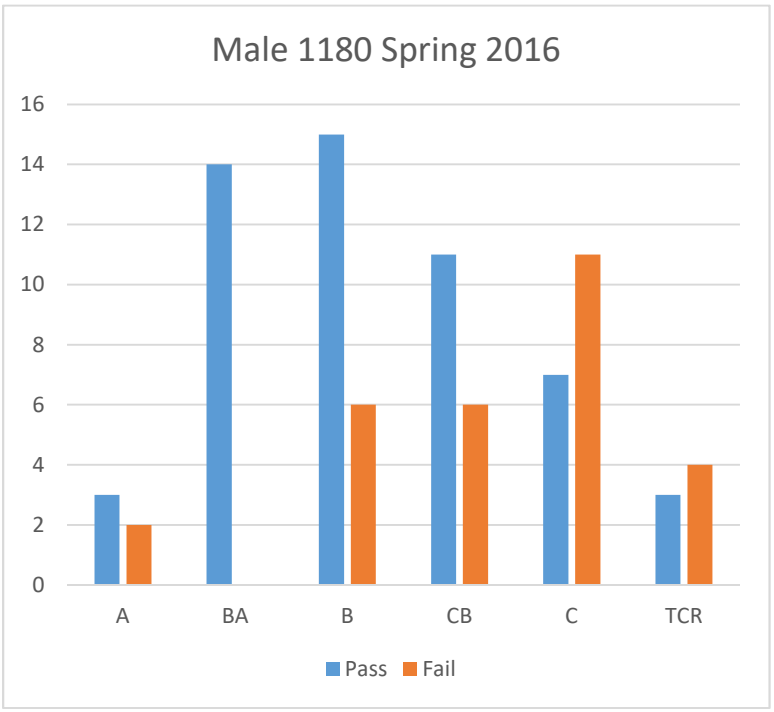


Figure 5: Spring 2016 combined placements via MATH 1180

1180 Score	Pass	Fail
A	5	2
BA	17	0
B	20	6
CB	14	6
C	7	15
TCR	6	4

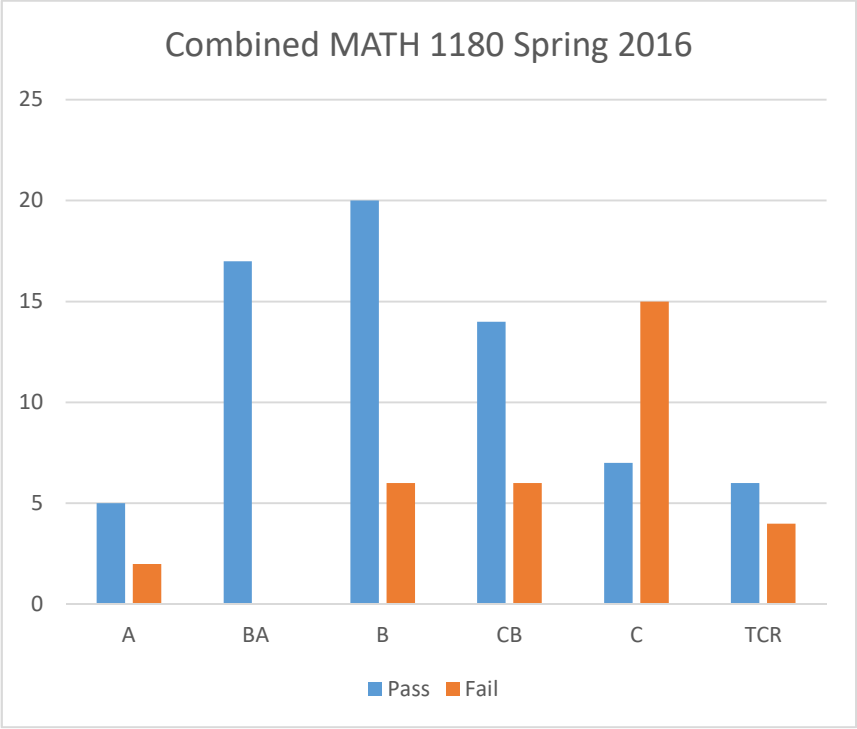


Figure 6: Fall 2016 Female placements via MATH 1180

1180 Score	Pass	Fail
A	1	0
BA	0	0
B	1	0
CB	1	0
C	3	0
TCR	2	0

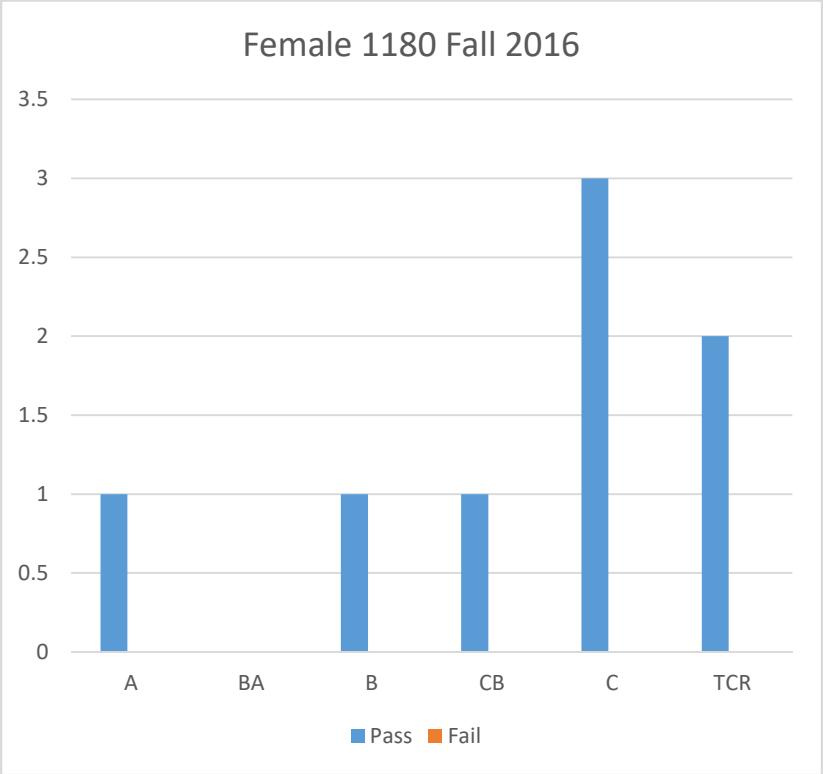


Figure 7: Fall 2016 Male placements via MATH 1180

1180 Score	Pass	Fail
A	4	0
BA	6	0
B	10	1
CB	9	4
C	7	7
TCR	19	3

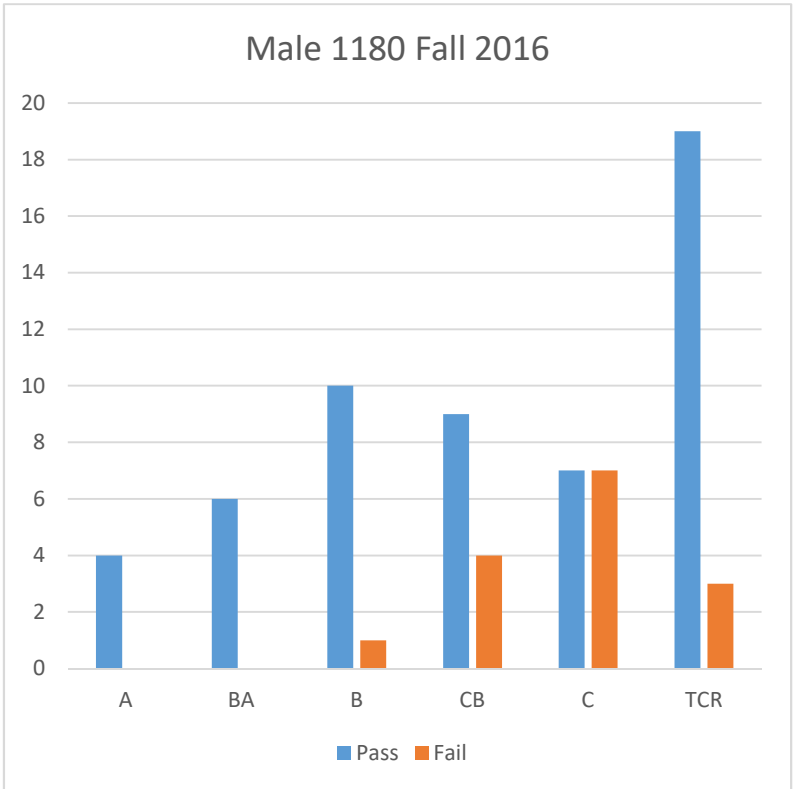
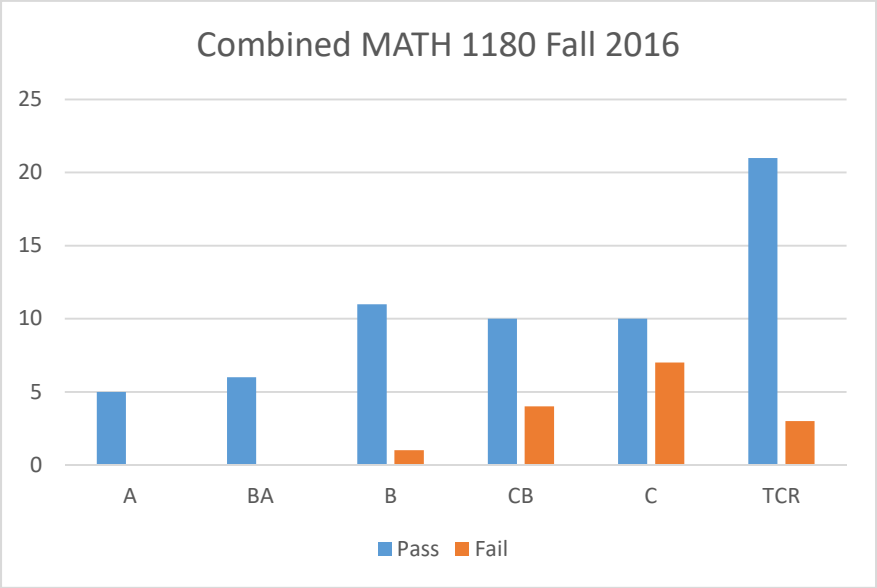


Figure 8: Fall 2016 Combined placements via MATH 1180

1180 Score	Pass	Fail
A	5	0
BA	6	0
B	11	1
CB	10	4
C	10	7
TCR	21	3



Data from both the spring and fall 2016 semesters indicates that the females that were placed by their Pre-Calculus score earned credit for Calculus 1 as long as they earned a CB or higher. All females that earned a C in Pre-Calculus in the spring did not successfully earn credit at the end of Calculus 1, while all who earned a C in Pre-Calculus in the fall did successfully earn credit. Male students had a greater variability in the data, but based on figures 4 and 7, the higher a grade from Pre-Calculus, the better chance the student had to be successful in Calculus. This variability in the data is evident in Figure 4 as two (40%) of students that earned an A in MATH 1180 were not successful in Calculus 1. As with the females, as long as the student earned a CB grade, then the data shows that they had a 100% chance of success in Calculus. However, when looking at both genders, Figures 4 and 7 show that at a C, the same or more students were unsuccessful than were successful in Calculus.

It is also interesting to note that 57% of students with transfer credits for Pre-Calculus in the spring were not successful in Calculus, while 14% in the fall were unsuccessful. This could

stem from the fact that different institutions prepare their students for their Calculus classes differently. Therefore, if students take Pre-Calculus at an institution that has different expectations for their Calculus students than Western Michigan University, then these students might not be prepared for Calculus at Western Michigan University when they transfer.

ACT

After Pre-Calculus scores, ACT scores were the next most popular placement method. Of the 137 students enrolled in the spring 2016 semester and 154 students in the fall 2016 semester, 27 (20%) and 49 (32%) students respectively were placed into Calculus based on their ACT math scores. Students must earn at least a 27 on the ACT math section to be automatically placed into Calculus 1. Therefore, only scores above a 27 are considered. Beginning with spring 2016 and then fall 2016 semesters, the following tables and charts show information on their success in the course.

Figure 9: Spring 2016 Female placements via ACT

ACT Score	Pass	Fail
29	1	0
28	1	0

Figure 10: Spring 2016 Male placements via ACT

ACT Score	Pass	Fail
34	1	0
32	1	0
31	2	0
30	1	1
29	3	1
28	0	5
27	8	2

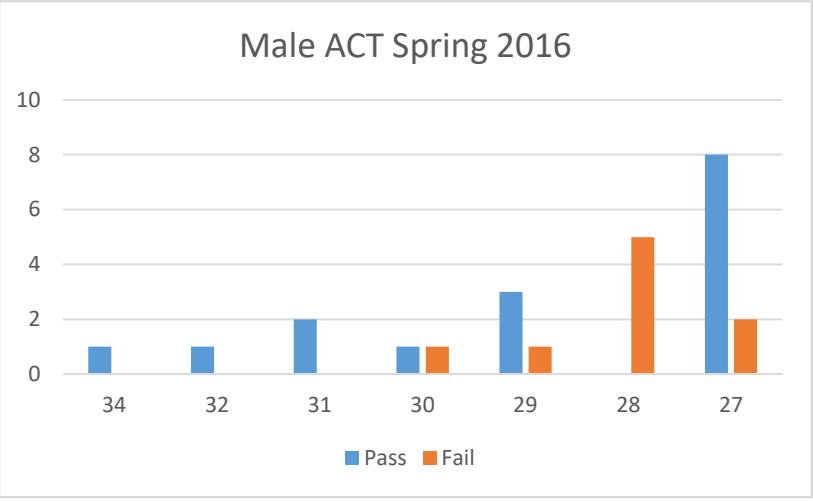


Figure 11: Spring 2016 Combined placements via ACT

ACT Score	# Pass	# Fail
34	1	0
32	1	0
31	2	0
30	1	1
29	4	1
28	1	5
27	8	2

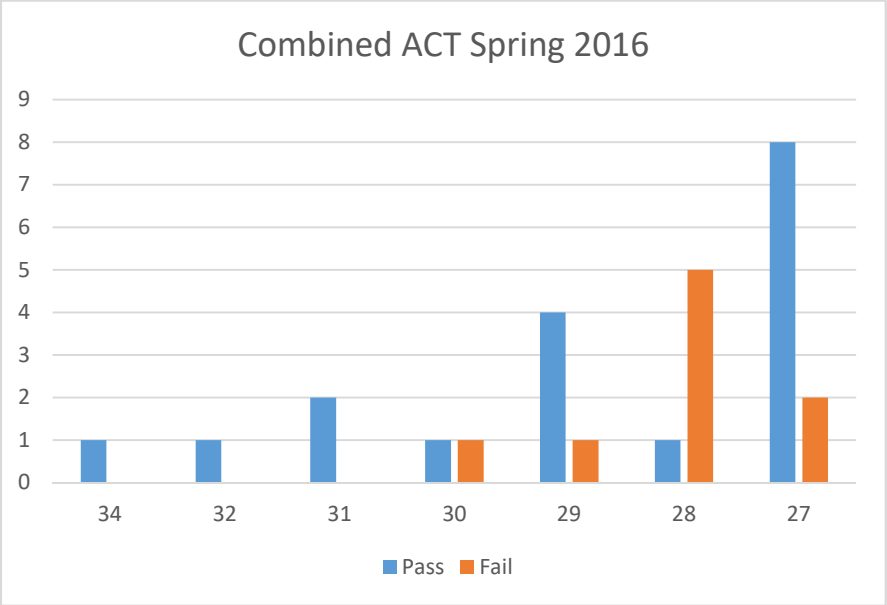


Figure 12: Fall 2016 Female placements via ACT

ACT Score	# Pass	# Fail
32	2	0
30	1	0
28	2	1
27	5	0

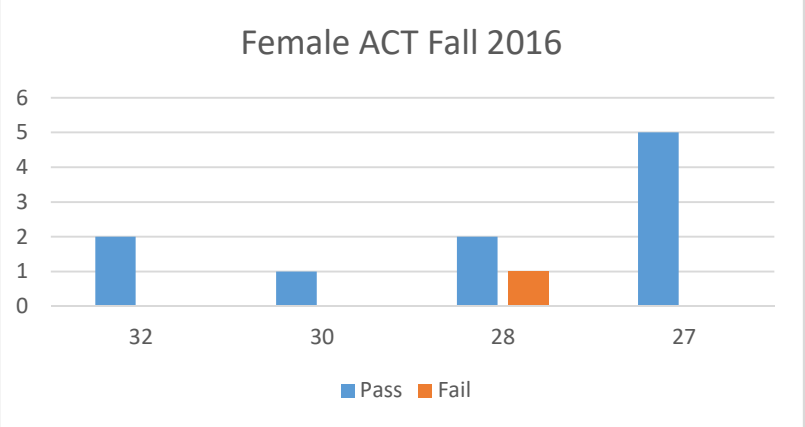


Figure 13: Fall 2016 Male placements via ACT

ACT Score	# Pass	# Fail
34	2	0
33	1	0
31	3	0
30	3	0
29	5	1
28	11	0
27	11	1

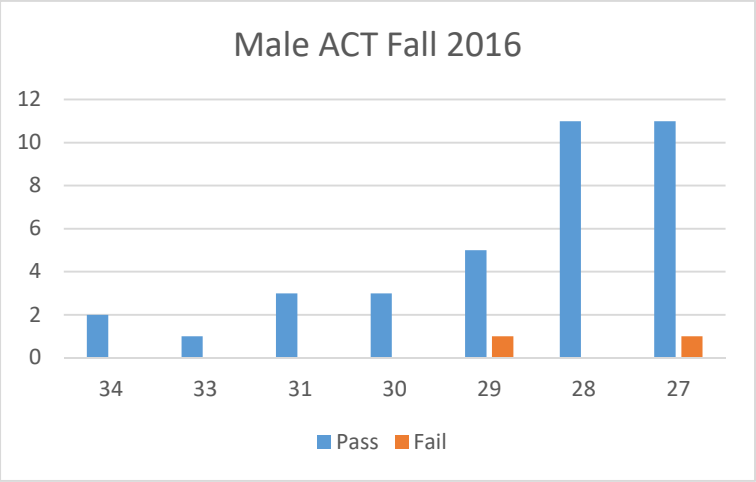
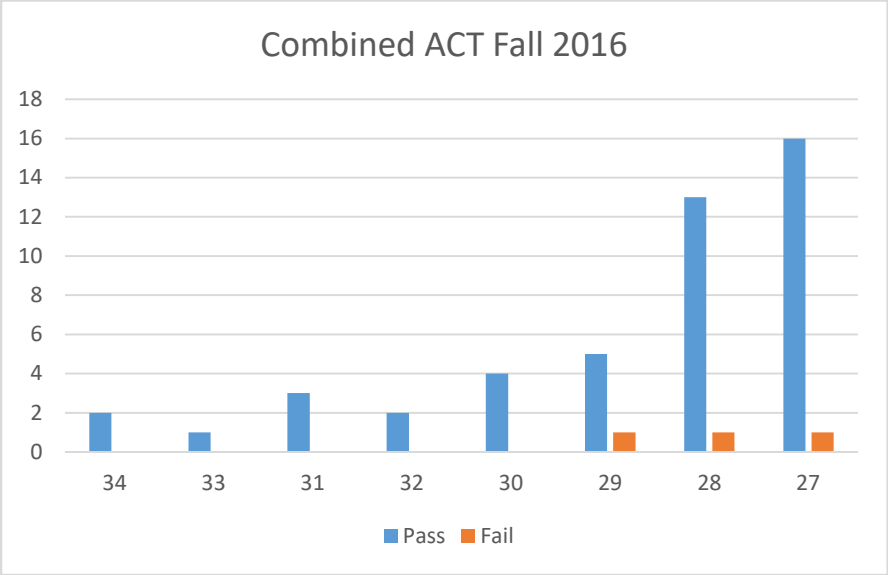


Figure 14: Fall 2016 Combined placements via ACT

ACT Score	Pass	Fail
34	2	0
33	1	0
31	3	0
32	2	0
30	4	0
29	5	1
28	13	1
27	16	1



Data from both the spring and fall 2016 semesters indicates that most of the females that were placed by their ACT score earned credit for Calculus. In fact, only one female student for those two semesters was unsuccessful in the course, and they were placed with an ACT score of 28, which is on the lower end of the placement scale. Similar to placement with Pre-Calculus scores, Male students had a greater variability in the data, but it is clear that the higher ACT math score earned, the better the individual student performed in Calculus. This variability is evident from Figure 13 showing that 95% of males placed for the fall 2016 by their ACT scores were successful, while Figure 10 shows only 64% of males from the spring 2016 were successful. This most likely stems from the time gap in-between their last class, most likely in high school, and enrolling in Calculus 1.

Advisor Override

Finally, the last placement method that is used is an advisor override. Of the 137 enrolled in the spring and 154 in the fall, 7 (5%) and 15 (10%) students respectively were placed from advisor overrides. This method is used when a student does not meet the requirements to enroll in the course, but an advisor makes an exception and enrolls them in the course anyways. Beginning with spring 2016 and then fall 2016 semesters, below are tables that show information on their success in the course.

Figure 15: Spring 2016 placements via Advisor Override

Female		Male		Combined	
Pass	Fail	Pass	Fail	Pass	Fail
1	0	2	4	3	4

Figure 16: Fall 2016 placements via Advisor Override

Female		Male		Combined	
Pass	Fail	Pass	Fail	Pass	Fail
6	0	8	1	14	1

From the data, it is clear that this method is not used often, and for a good reason. It seems to be a risky decision to place a student into a class that, according to departmental standards and requirements, they are not ready to handle. The fall semester does see a higher number of advisor overrides because many students may be waiting for credits to transfer when they are registering. Therefore, an advisor override is needed to get into the course. Thus, these students may be qualified to take the course; they just did not have the required credits when they registered. On the other hand, the spring semester has a lot more students that were not

successful after being placed with an advisor override. In fact, Figure 15 shows that more were unsuccessful than were successful. This is most likely because students who waited to take their math class for years after their last math class needed to get into Calculus when they were not ready. The number of students with advisor overrides that are unsuccessful is high, and ideally should be lower. Advisor overrides should be used in special circumstances, and it is clear from the spring data, that this may not always be the case.

Discussion of Placement

From the placement data, there are some interesting findings. To begin, I believe that the ACT placements require no action. The data shows that ACT scores are a good indicator of success in the course, especially for females. There were only a few instances where ACT scores show lack of success for males, but these are most likely statistical outliers in the data. Next, there was a lot of variability in the Pre-Calculus method of placement. While data from the fall 2016 semester showed no concern for students with good scores from Pre-Calculus, the data from the spring showed some variability. There were far more students that were placed using Pre-Calculus in the spring, and far more were unsuccessful in Calculus no matter what their Pre-Calculus grade was. During these semesters at Western Michigan University, Pre-Calculus (MATH 1180) was not currently under coordination like Calculus 1. Therefore, different instructors could teach the course, and could teach the course differently. Therefore, not all students were assessed in the same way, and their grades may not have been equivalent. In order to get data that is more reliable from students placed via their Pre-Calculus grades, MATH 1180 needs to be coordinated in a manner such that all students are assessed similarly and consistently. Only then can conclusion be made based on the MATH 1180 placement data. Starting in spring 2017, MATH 1180 started coordination. Therefore, data that will be more reliable will be

available once those students that took Pre-Calculus in the spring of 2017 enroll in and complete Calculus 1 in the fall of 2017. Finally, the data from advisor overrides is very concerning. Data from the spring semester shows that some students were allowed to enroll in the course when they should not have been able to do so. Obviously, there are special circumstances that exist that may warrant an advisor override, but there needs to be a check on these. If a student truly needs an advisor override, and has the sufficient knowledge to be enrolled in the course, then they should be able to demonstrate this. I am recommending that in order for students to receive an advisor override, they need to demonstrate that they are ready for Calculus. This can be done through a written department test or through online software such as ALEKS (Assessment and LEarning in Knowledge Spaces). If students need an advisor override due to a special circumstance, then a second method should be used to double check that they are ready for the rigor of Calculus. In summary, placement by ACT scores works well, placement by MATH 1180 scores is somewhat vague due to possible inconsistencies in teaching of the course, and advisor overrides may be overused. Course instructions should pay the most attention to students who are placed via an advisor override and those who earned a "C" in MATH 1180. These are the greatest indicators that students may be unsuccessful in Calculus 1.

Progression

After investigating how the students were placed into Calculus, it was important to investigate how they progressed and persisted through the course

Initial Assessment

. The first metric used to gauge this is the initial assessment that students take during the first week of school using the online program ALEKS. The initial assessment is taken un-

proctored and on the student's own time. While students are encouraged to take it without the aid of books, internet, technology, and other outside help, there is no way to verify if they do so. Therefore, data from the initial assessment can be un-reliable. Beginning with spring 2016 and then fall 2016 semesters, below are tables and charts that show the success of the students. For Figures 19 and 22, each student's initial assessment score is plotted against their final course grade. Their course grade was converted into a numerical representation, and the table to the left of the graph shows the letter grade that each number represents.

Figure 17: Spring 2016 Female initial assessment compared to success in course

Initial Assessment Score	Pass	Fail
0-24.9%	2	0
25-49.9%	5	1
50-74.9%	12	3
75-100%	1	0

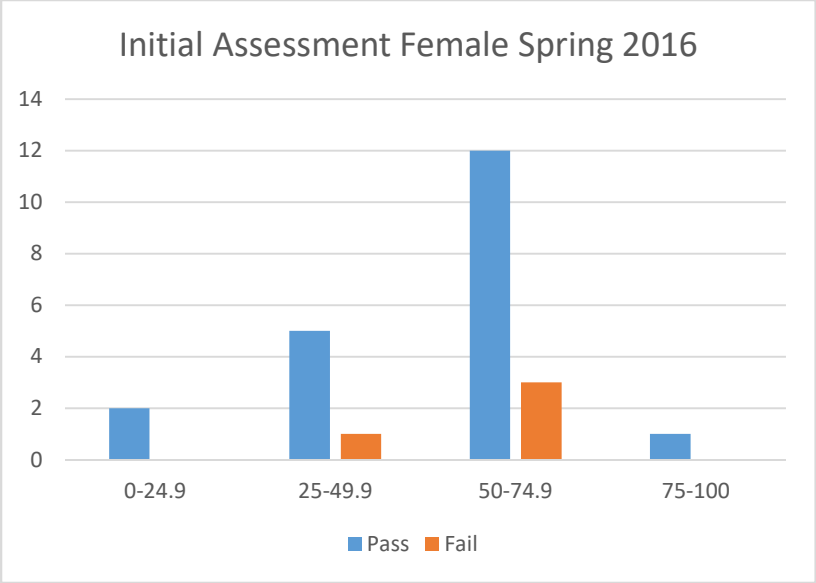


Figure 18: Spring 2016 Male initial assessment compared to success in course

Initial Assessment Score	Pass	Fail
0-24.9%	4	10
25-49.9%	21	13
50-74.9%	38	16
75-100%	9	2

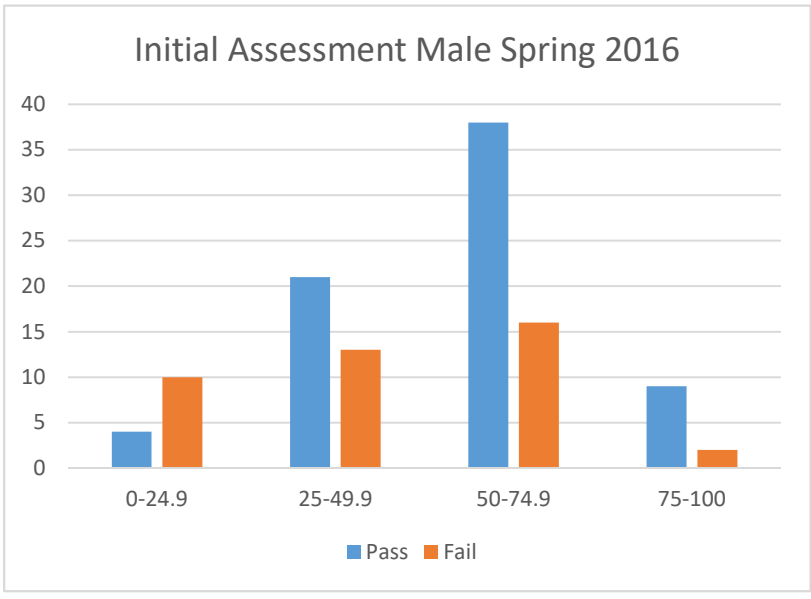


Figure 19: Spring 2016 Combined initial assessment compared to success in course

A	8
BA	7
B	6
CB	5
C	4
DC	3
D	2
E/X	1

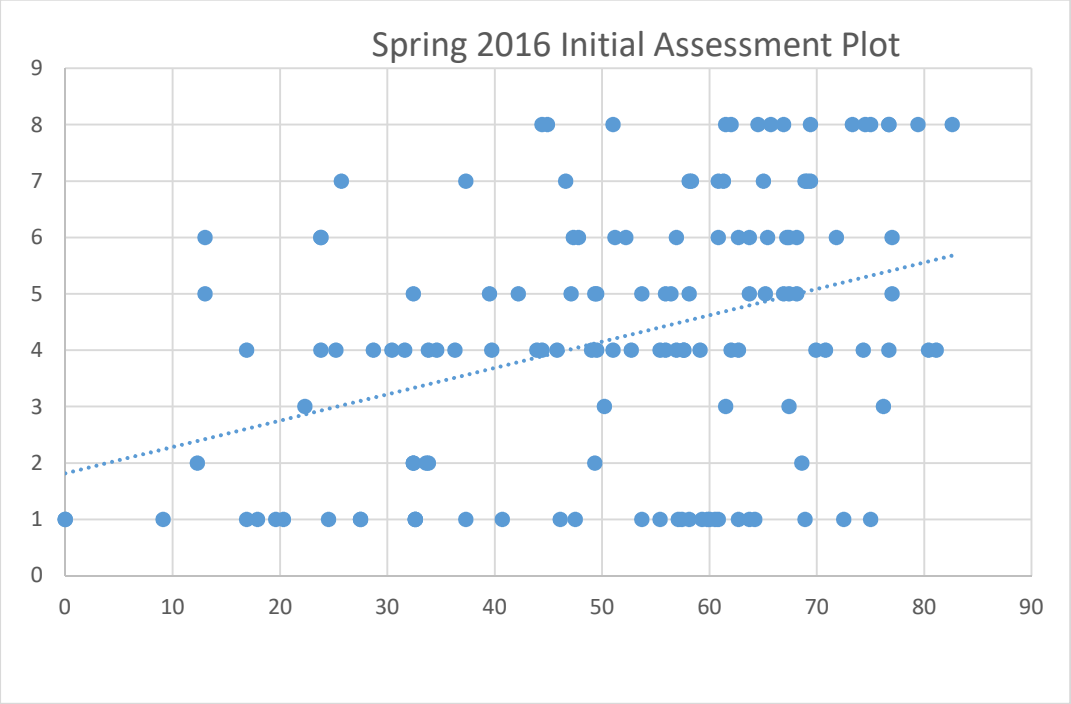


Figure 20: Fall 2016 Female initial assessment compared to success in course

Initial Assessment Score	Pass	Fail
0-24.9%	3	0
25-49.9%	13	0
50-74.9%	12	1
75-100%	3	0

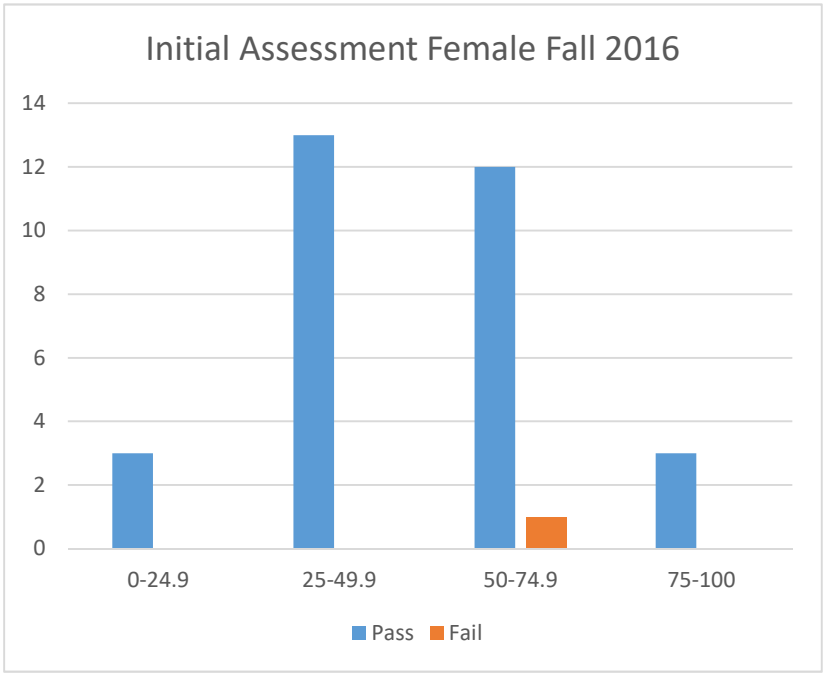


Figure 21: Fall 2016 Male initial assessment compared to success in course

Initial Assessment Score	Pass	Fail
0-24.9%	15	5
25-49.9%	26	9
50-74.9%	46	3
75-100%	17	1

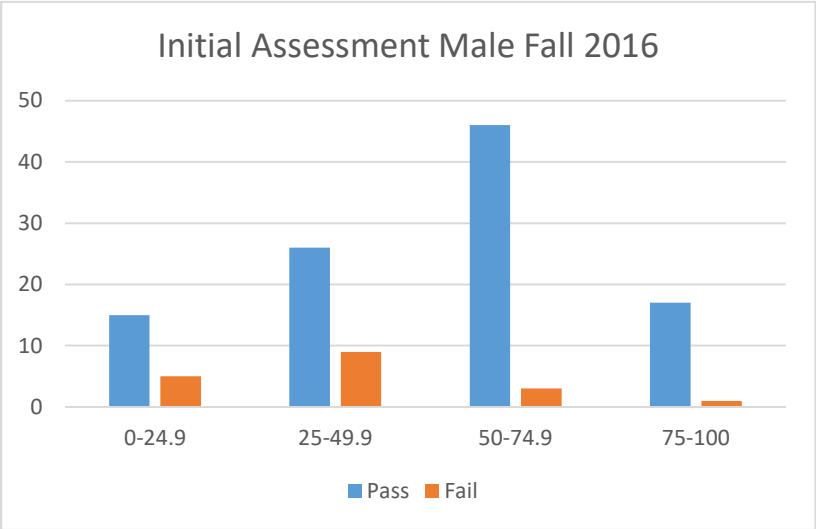
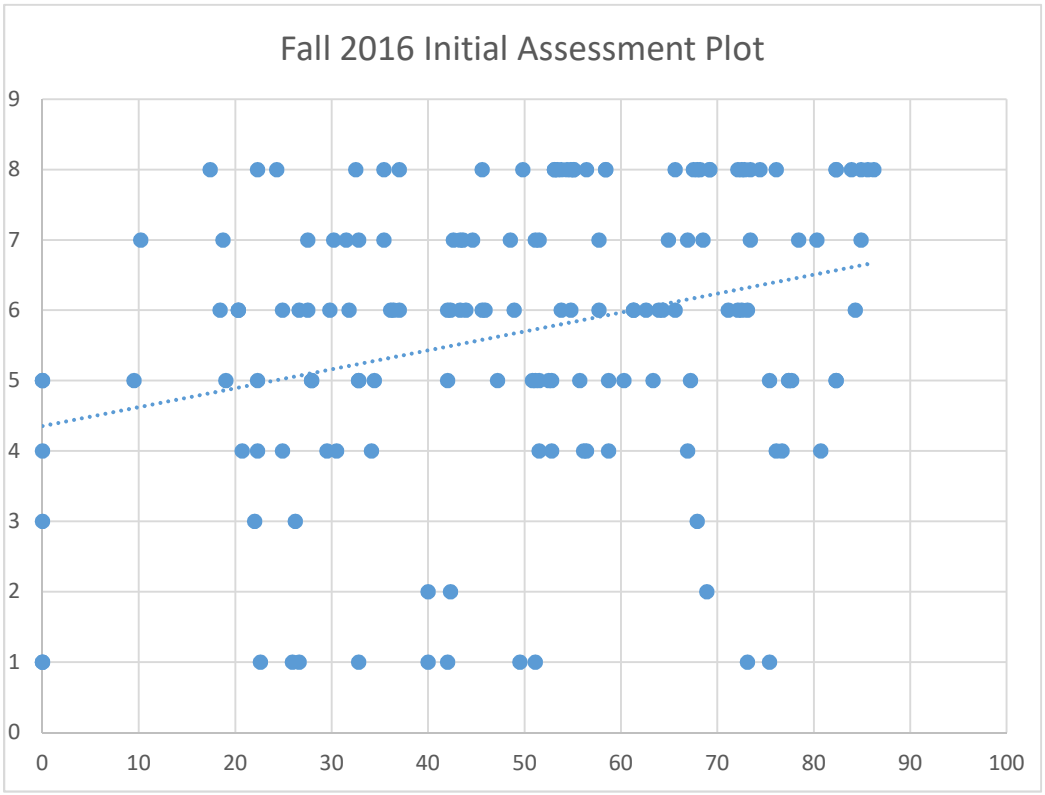


Figure 22: Fall 2016 Combined initial assessment compared to success in course

A	8
BA	7
B	6
CB	5
C	4
DC	3
D	2
E/X	1



Data from the initial assessment does show a strong tendency for both males and females to pass the course with a better initial assessment score. However, when the data for both males and females is combined, as in Figures 19 and 22, the results are interesting. The plots created using each student's initial assessment score against their final course grade resulted for both semesters to show no clear trend. Excel was able to put a linear trend line to the data, but it does not show a strong correlation between initial assessment scores and final course grades. There were students that did well on the initial assessment that were unsuccessful in the course, and students that did not do well on the initial assessment that did very well in the course. Therefore, it is clear that the initial assessment metric from ALEKS does not provide much insight on how successful a student will be in Calculus 1, and thus is not a good early warning indicator for instructors to use to predict success.

Mastery 1

About a week after students take the initial assessment, they take their first mastery exam on ALEKS. This exam tests pre-requisite knowledge that is needed in order to be successful in the course. Unlike the initial assessment, this exam is taken in class and is proctored. After the in-class attempt, students have two additional attempts to earn a higher score during proctored lab hours. Therefore, students are not able to use any outside resources to aid them on the exam. A 75% on the mastery exam is a passing score, and sufficient prior knowledge to succeed in the course. If students are unable to attain this passing score, their final course grade is lowered by 5%. For spring 2016 and fall 2016 semesters, the success of the students is shown below.

Figure 23: Spring 2016 Female mastery 1 compared to success in course

Mastery 1 Score	Pass	Fail
0-24.9%	2	0
25-49.9%	0	2
50-74.9%	8	1
75-100%	10	1

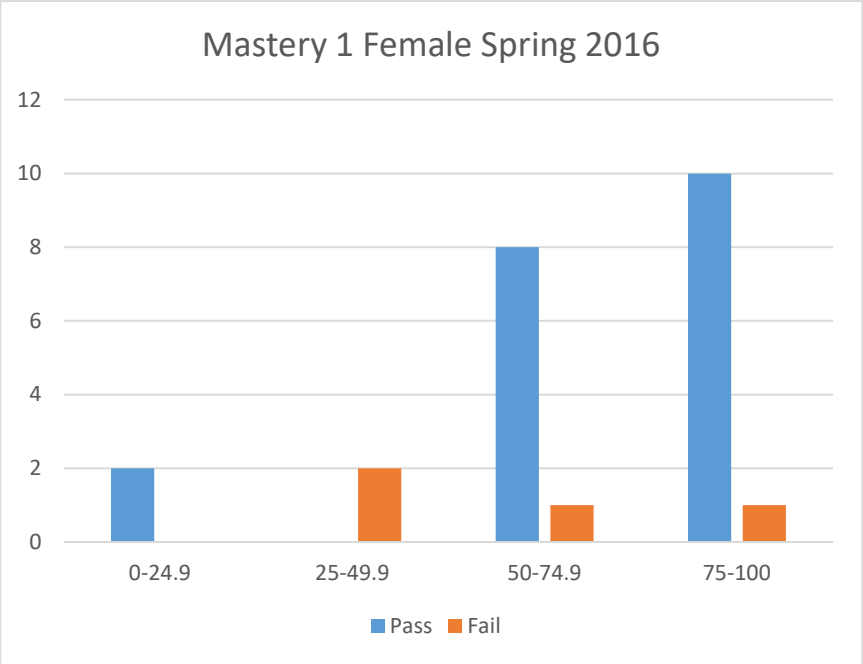


Figure 24: Spring 2016 Male mastery 1 compared to success in course

Mastery 1 Score	Pass	Fail
0-24.9	1	7
25-49.9	5	9
50-74.9	18	17
75-100	49	7

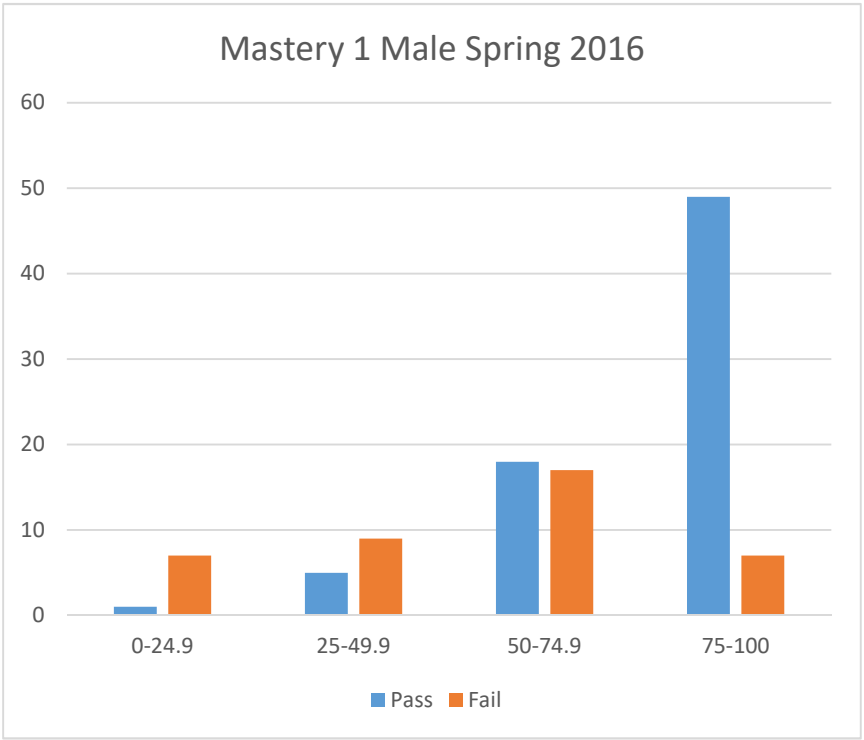


Figure 25: Spring 2016 Combined mastery 1 compared to success in course

A	8
BA	7
B	6
CB	5
C	4
DC	3
D	2
E/X	1

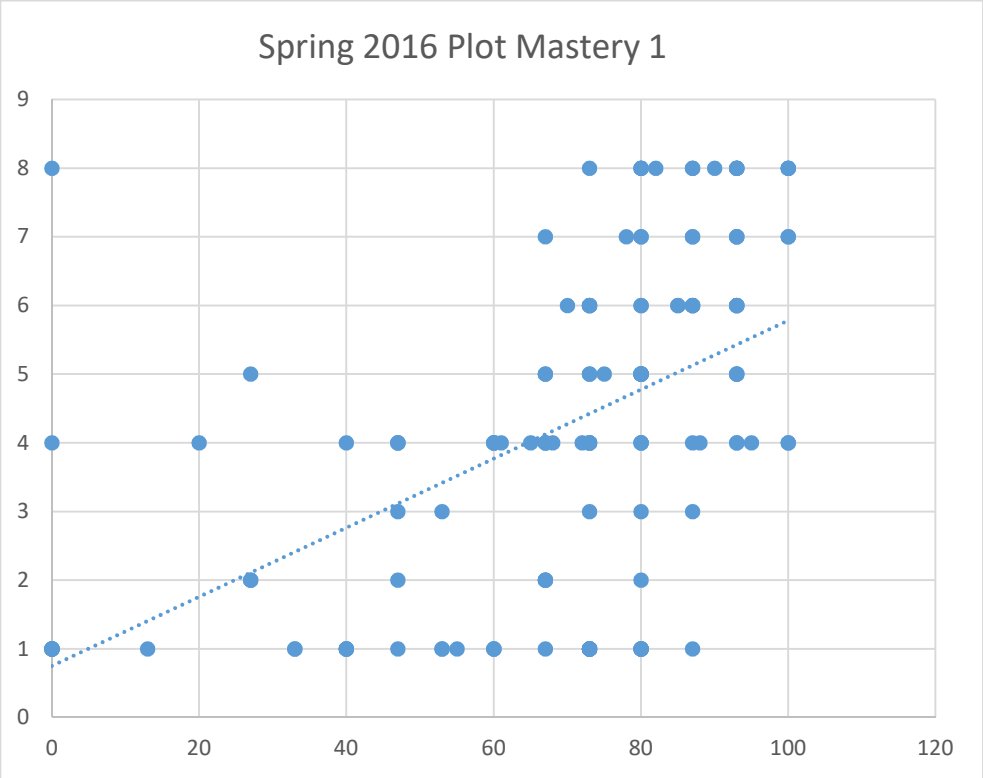


Figure 26: Fall 2016 Female mastery 1 compared to success in course

Mastery 1 Score	Pass	Fail
0-24.9%	6	1
25-49.9%	2	0
50-74.9%	10	0
75-100%	13	0

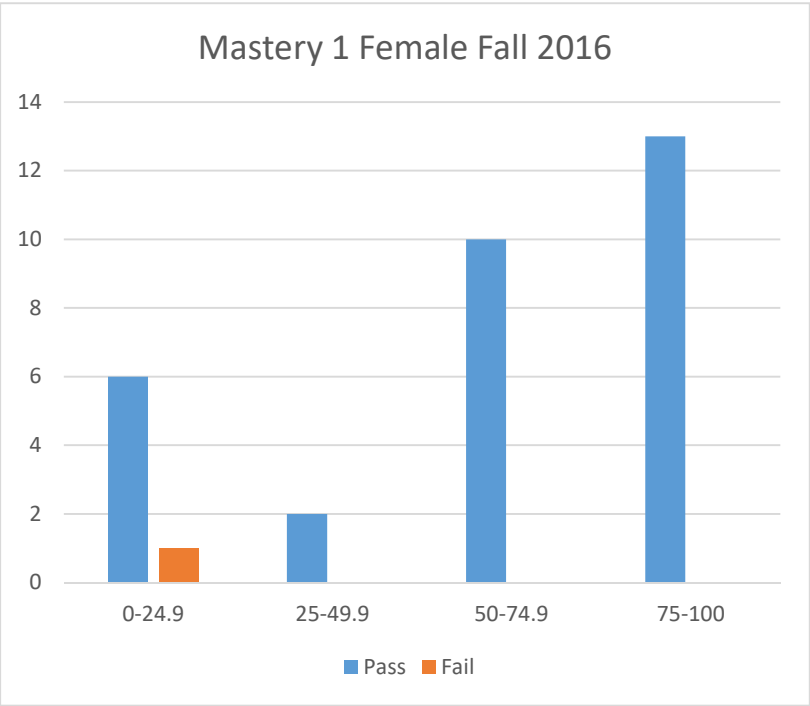


Figure 27: Fall 2016 Male mastery 1 compared to success in course

Mastery 1 Score	Pass	Fail
0-24.9%	11	8
25-49.9%	23	7
50-74.9%	36	3
75-100%	34	0

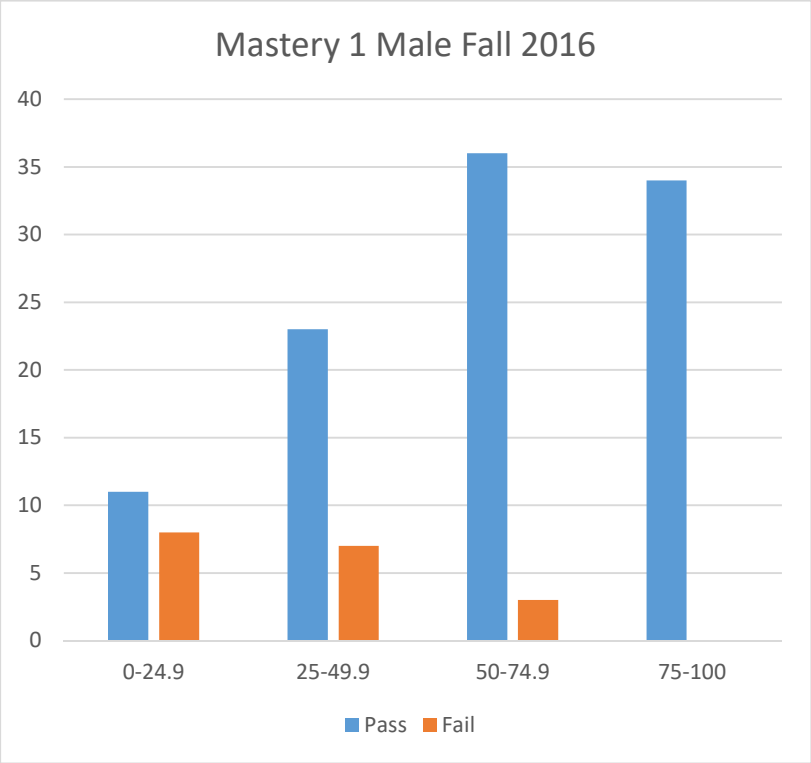
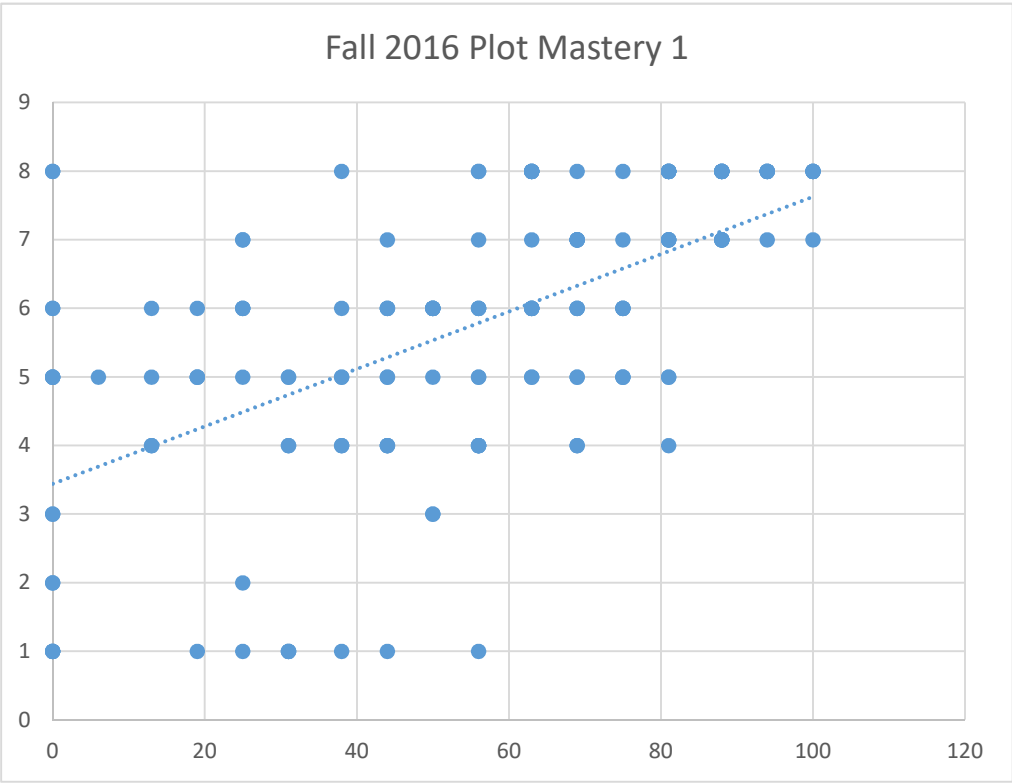


Figure 28: Fall 2016 Combined mastery 1 compared to success in course

A	8
BA	7
B	6
CB	5
C	4
DC	3
D	2
E/X	1



Compared to the initial assessment data, the data gathered from the mastery 1 exam is a better indicator of success. This is directly attributed to the fact that all students take this assessment in a proctored environment. Thus, the results are credible and reliable. You can see that there is a clear trend in the fact that the higher the score on the mastery 1 exam, the better chance of success in the course. In fact, if students earn at least the 75% that is deemed passing, they are highly likely to be successful in the course. For the fall 2016 semester, everybody that earned above a 75% was successful in the course. For the spring semester, 88% of students that met or exceeded the 75% were successful in the course. This is especially evident in the plots with the combined data. One important note about figures 25 and 28 is that unlike the initial assessment, a single point may represent more than one student. This results in the appearance of less data, when in fact the same amount of data is present. From this data, there is a clear trend in the fact that if students have a better grasp on the required prior knowledge, then they will do better in the course. This shows the importance of having the students coming into Calculus prepared with prerequisite material. Data from mastery 1 can and should be considered as an early warning indicator of success/failure in the course. As soon as results are available for instructors, they should take appropriate action with identified at-risk students.

Mastery 2

After looking at the prior knowledge that mastery 1 assesses, the knowledge that was attained during the first two-thirds of the semester was also examined. About two-thirds of the way through the semester, students take their second mastery exam, which assesses knowledge of limits and derivative rules, two of the three major concepts of the course. Similar to the first mastery exam, a 75% is considered passing, the exams were taken in a proctored environment,

and students were given two addition attempts to earn a better score during proctored lab hours. In addition, if a passing score of at least 75% is not earned, a 5% deduction is taken from the students final course grade. Beginning with spring 2016 and then fall 2016 semesters, below are tables and charts that show the success of the students.

Figure 29: Spring 2016 Female mastery 2 compared to success in course

Gateway 2 Score	Pass	Fail
0-24.9	0	2
25-49.9	0	1
50-74.9	6	1
75-100	14	0

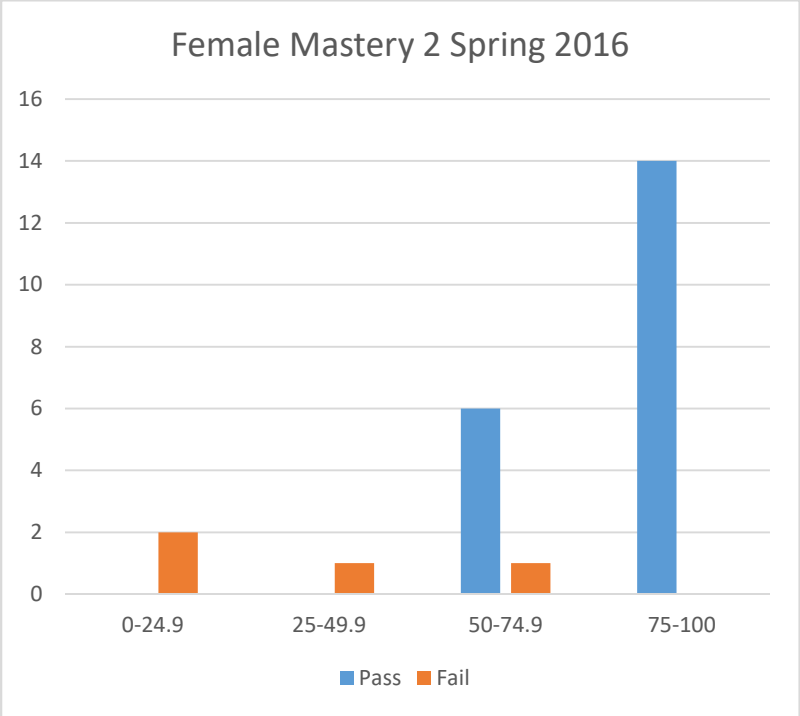


Figure 30: Spring 2016 Male mastery 2 compared to success in course

Gateway 2 Score	Pass	Fail
0-24.9	1	14
25-49.9	0	11
50-74.9	23	13
75-100	48	2

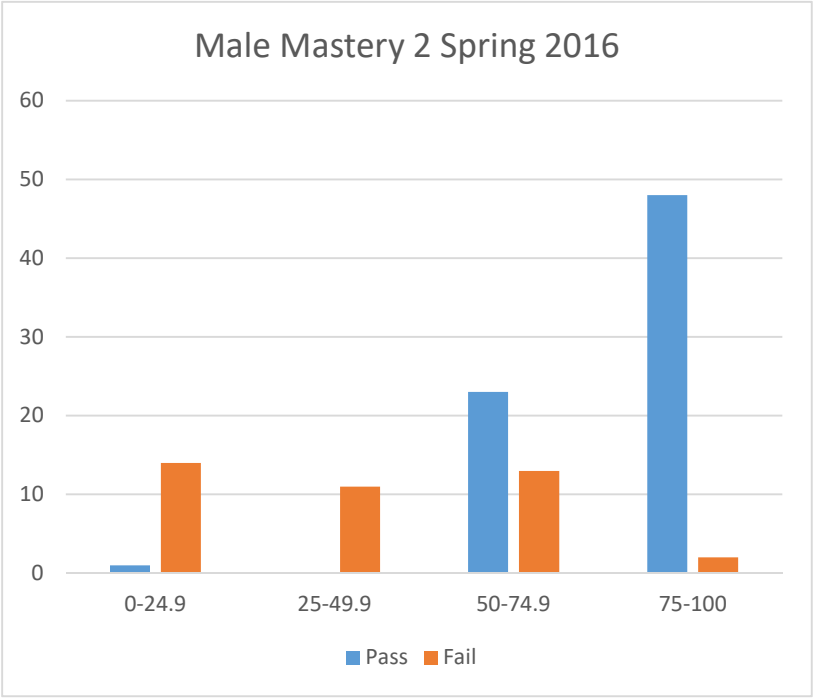


Figure 31: Spring 2016 Combined plot mastery 2 compared to success in course

A	8
BA	7
B	6
CB	5
C	4
DC	3
D	2
E/X	1

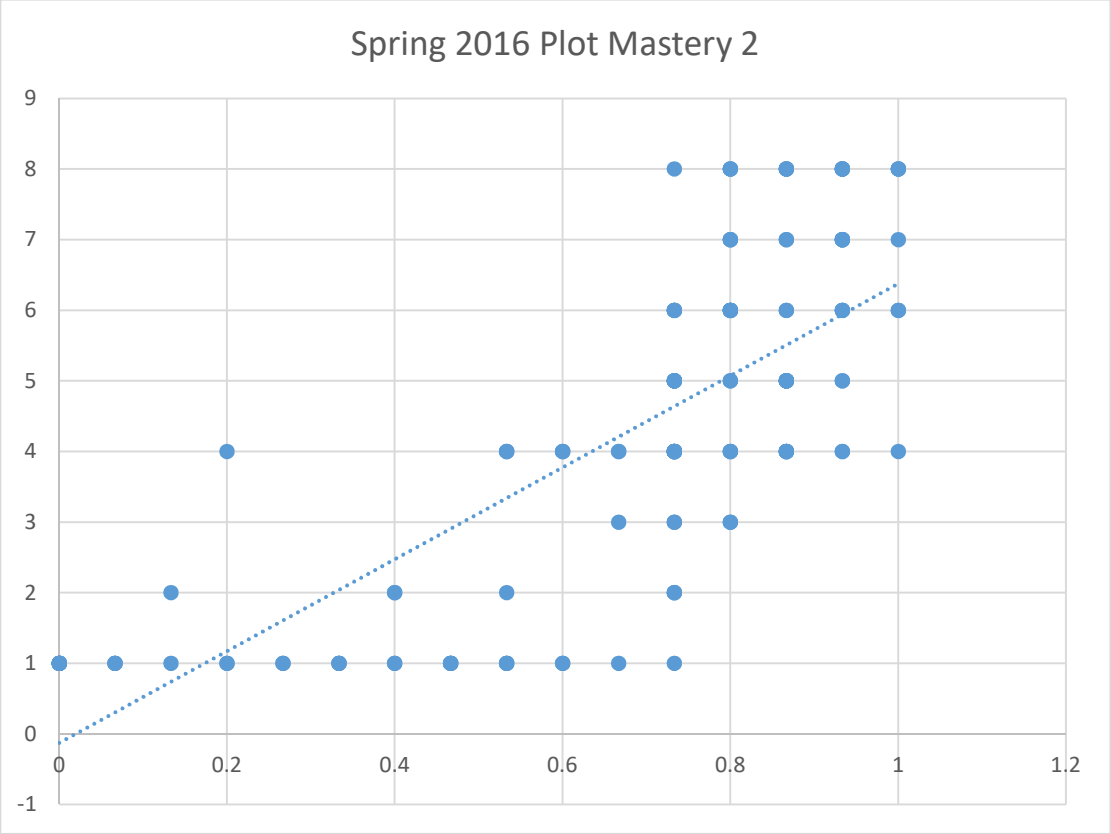


Figure 32: Fall 2016 Female mastery 2 compared to success in course

Gateway 2 Score	Pass	Fail
0-24.9	3	0
25-49.9	1	1
50-74.9	5	0
75-100	22	0

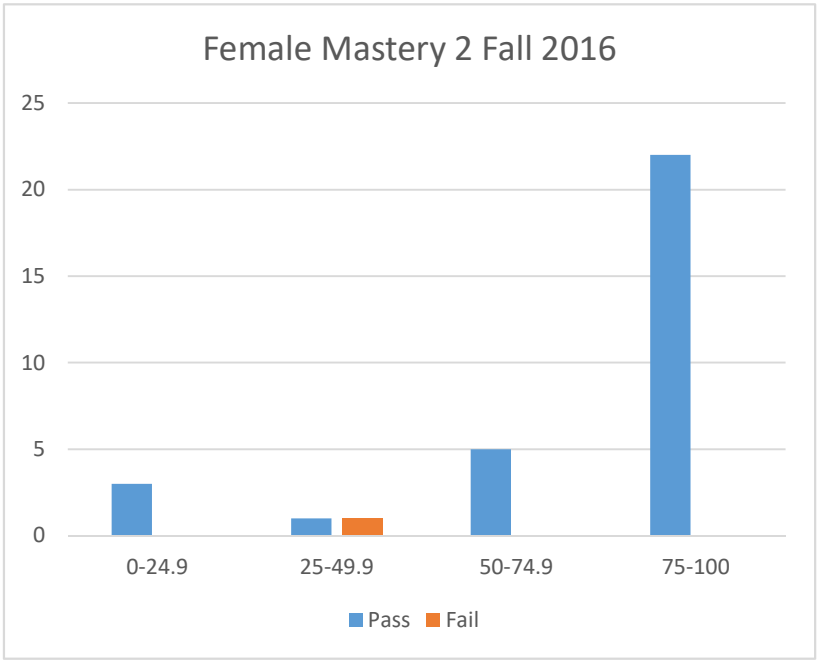


Figure 33: Fall 2016 Male mastery 2 compared to success in course

Gateway 2 Score	Pass	Fail
0-24.9	15	11
25-49.9	6	4
50-74.9	20	2
75-100	63	1

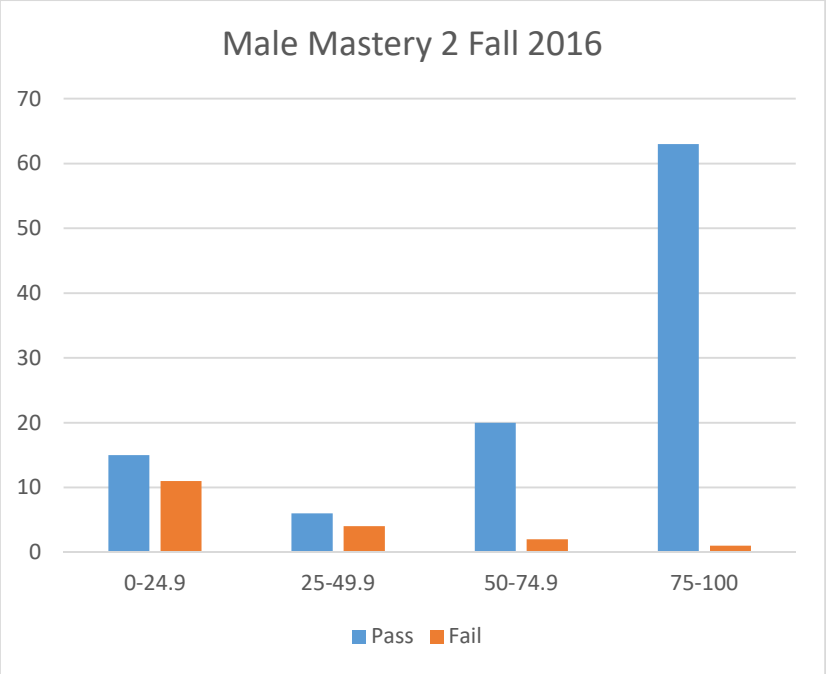
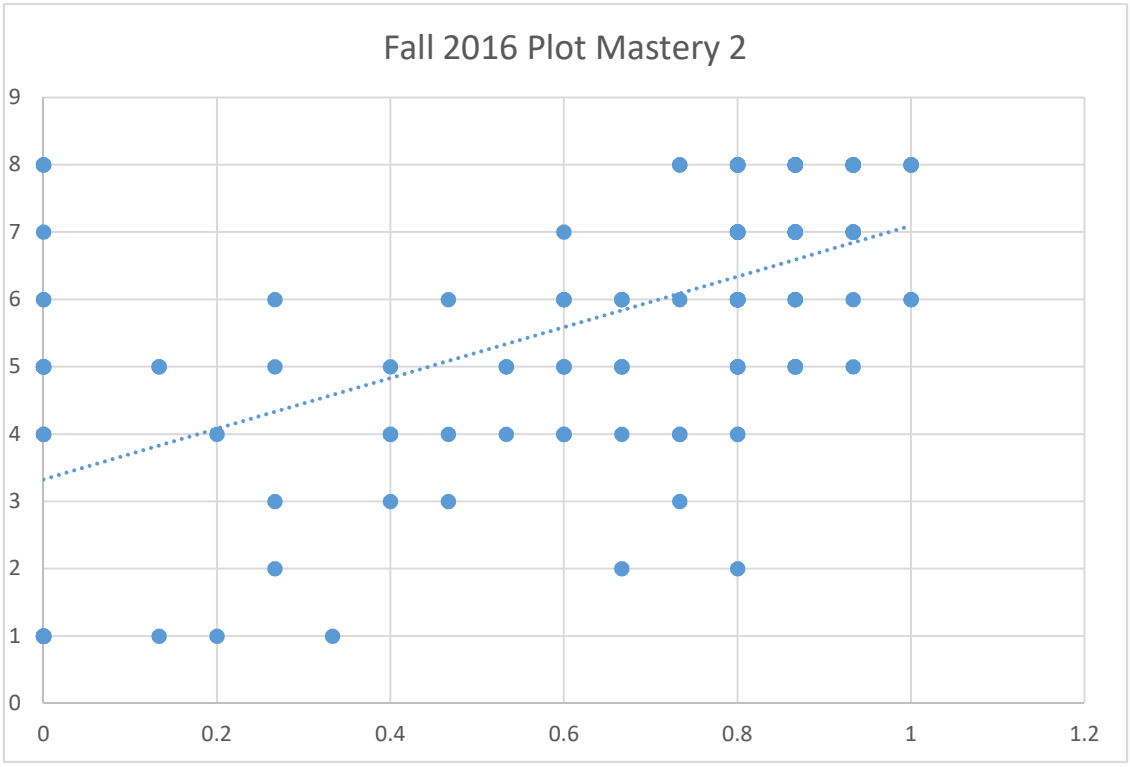


Figure 34: Fall 2016 Combined plot mastery 2 compared to success in course

A	8
BA	7
B	6
CB	5
C	4
DC	3
D	2
E/X	1



Due to the content of the second mastery exam being key content from Calculus 1, it is not surprising that there is an even stronger correlation between scores on the exam, and success in the course. However, the trend is a lot more evident in the second mastery than the first because this exam covers content that is taught in the course, and is not entirely pre-requite knowledge. Figures 26 and 29 show clear trends with the females in that the higher scores on the mastery exam, the more likely they are to succeed. In fact, if they attained the 75% passing score, 100% of students were successful in the course. Figures 27 and 30 show similar success for the males. Approximately 98% of males that attained 75% passing scores were also successful in the course. When each student is plotted as a data point for their score versus their final course grade, Figures 28 and 31 show a trend in their success. Data from mastery 2 can and should be considered as an early warning indicator of success/failure in the course. As soon as results are available for instructors, they should take appropriate action with identified at-risk students.

Mid-term Grades

After looking at the mastery exams, the last piece of data from the progression category is the mid-term grades.

Every Calculus 1 instructor releases a mid-term grade so that students can see how they are doing at the halfway point in the semester. This allows the students to take time to think about how they are progressing in the course, and if they should consider new strategies to be successful in the course, seek other assistance, or as a last resort withdraw from the class before the withdraw deadline. While all instructions currently release mid-term grades, this has not

always been the case. Below are charts that detail data on mid-term grades being released for both spring and fall semesters of 2014 and 2015. Note that "HC" next to an instructor's number indicates that it was an honors college section.

Figure 35: Spring 2014 Mid-Term grade release compared to success

Spring 2014	Mid-Term Grade Released?	% unsuccessful
Instructor 1	Yes	44
Instructor 2	No	47
Instructor 3	Yes	15
Instructor 4	Yes	26

Figure 36: Fall 2014 Mid-Term grade release compared to success

Fall 2014	Mid-Term Grade Released?	% unsuccessful
Instructor 1	No	36
Instructor 2	No	41
Instructor 3 HC	No	12
Instructor 4	Yes	22
Instructor 5	Yes	50
Instructor 6 HC	Yes	13

Figure 37: Spring 2015 Mid-Term grade release compared to success

Spring 2015	Mid-Term Grade Released?	% unsuccessful
Instructor 1	Yes	50
Instructor 2	yes	26
Instructor 3	Yes	61
Instructor 4	Yes	31
Instructor 5	Yes	36

Figure 38: Fall 2015 Mid-Term grade release compared to success

Fall 2015	Mid-Term Grade Released?	% unsuccessful
Instructor 1	Yes	23
Instructor 2	No	37
Instructor 3 HC	Yes	19
Instructor 4	Yes	34
Instructor 5	Yes	74
Instructor 6 HC	Yes	8

In the four additional semesters of data analyzed, there were 21 sections of Calculus 1. Of the 21 sections, 5 (24%) of the instructors did not release mid-term grades to their students. 4 of those 5 classes fell into the top 9 classes with the highest percent of students not earning at least a "C" in the course. The fifth class was an honors section, and had the second lowest percent, which was just 4% higher than the lowest class, which was also an honors section. While there are some outliers in the data, there appears to be a direct correlation between the success rates of the students and if their mid-term grades are released. That is, by having their mid-term grades released, students were more aware of their status in the class and more likely to do something to improve their grades.

With data collected from the 2016 semesters, I was able to look more closely into success trends of the students. Below are charts and graphs detailing student success. Student grades were looked at to see if they were passing or failing when mid-term grades were released, and then compared to if they were passing or failing when final grades were released.

Figure 39: Spring 2016 Female Mid-Term grade compared to final grade

Mid Term	Pass	Fail
Pass	10	0
Fail	10	4

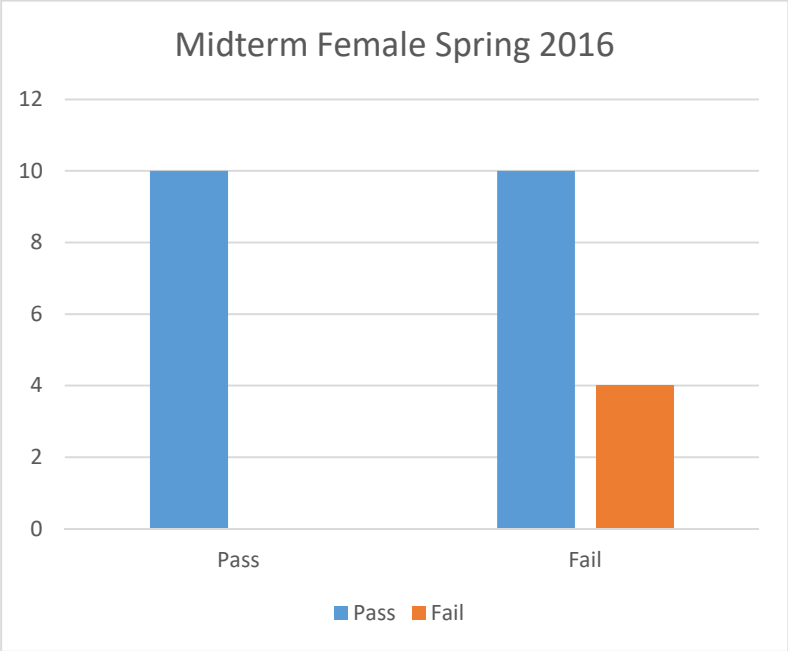


Figure 40: Spring 2016 Male Mid-Term grade compared to final grade

Mid Term	Pass	Fail
Pass	57	8
Fail	15	33

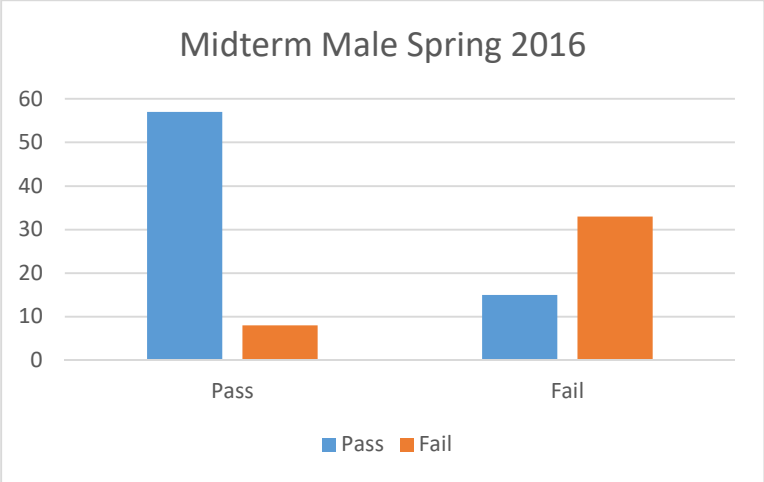


Figure *41: Spring 2016 Combined Mid-Term grade compared to final grade*

Mid Term	Pass	Fail
Pass	67	8
Fail	25	37

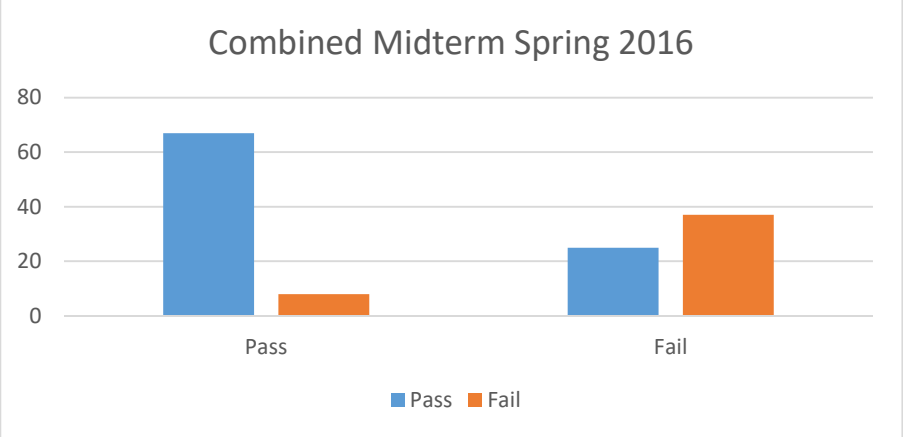


Figure 42: Fall 2016 Female Mid-Term grade compared to final grade

Mid Term	Pass	Fail
Pass	28	0
Fail	3	1

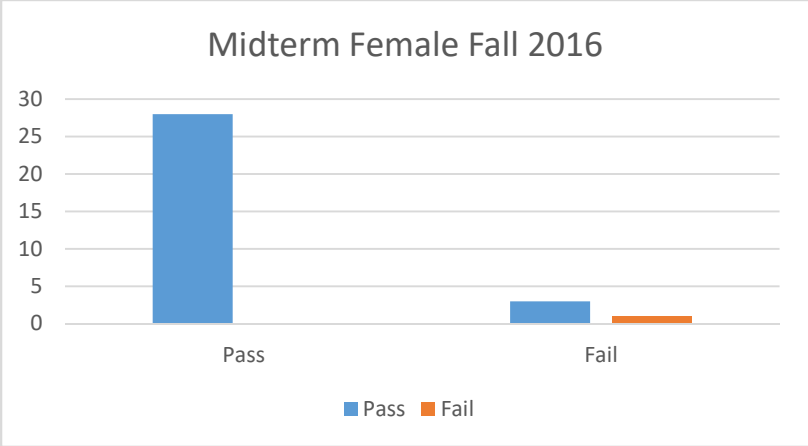


Figure 43: Fall 2016 Male Mid-Term grade compared to final grade

Mid Term	Pass	Fail
Pass	84	1
Fail	20	17

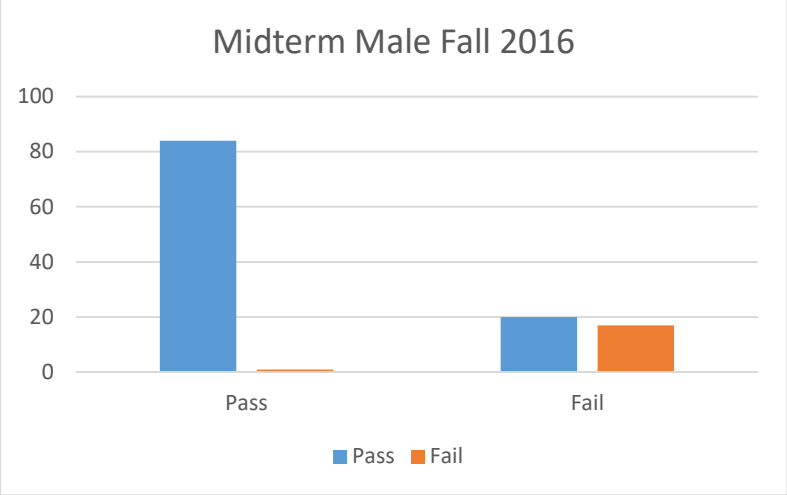
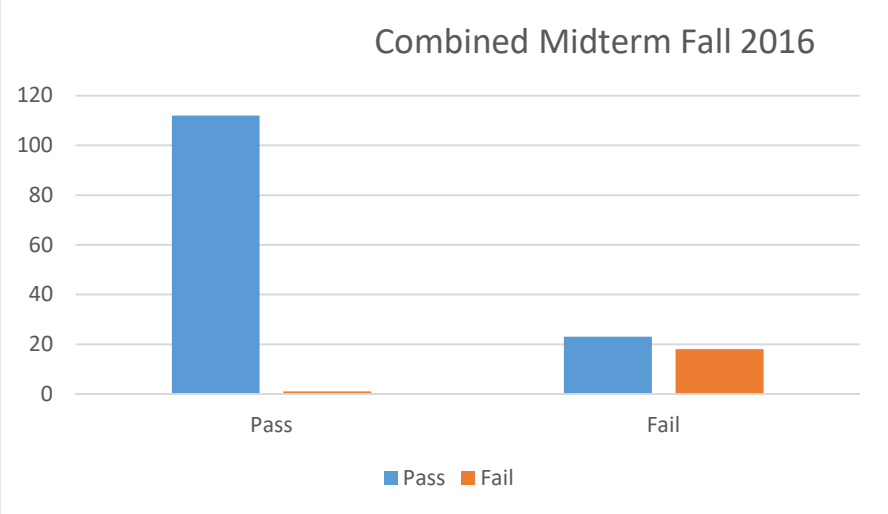


Figure 44: Fall 2016 Combined Mid-Term grade compared to final grade

Mid Term	Pass	Fail
Pass	112	1
Fail	23	18



Figures 38 and 41 both show strong correlation between success and having mid-term grades released. Both Figures show the majority of students passing at mid-term, ending the semester with a passing grade as well. These students were able to see how they were doing, and continue in their course. With the students that were failing at mid-term, Figures 38 and 41 show that 40% and 56% respectively were able to improve their failing grade to a passing grade to earn credit and progress to the next course. They were able to see their mid-term grade, and make necessary adjustments so that they could be successful in the course. I believe that this is a direct result of having access to their grades at the halfway point in the semester. Sprick (2013) argues that you want your students to know their status in your class at all times. Along with mid-term grades being released, each instructor uses Elearning, an online platform where instructors can, among other things, post grades for assignments. This allows students to see how they are doing in the course and on specific assignments. The fact that students have access to their grades at all times is a great benefit to them, and because of this, more students are able to be successful in Calculus 1.

Discussion about Progression

Overall, there are many different aspects to look at when considering progression through Calculus 1. First, there is the initial assessment. Currently, this assessment provides no indication of success to instructors. If we want this to be a reliable indicator of success, this assessment needs to be taken in a proctored environment similar to the mastery exams. This way, accurate data can be collected about their prior knowledge when they enter the course. Next, mastery exams 1 and 2 both provide clear data that predicts success in the course. Data from both mastery exams show that the higher you score on the exam, especially those that score at or above 75%,

which is deemed the passing score, will be successful in the course. I recommend no changes to these exams. However, instructors should use the results from these exams as an early warning indicator to help students that may be in danger of not being successful in the course. Finally, the importance of mid-term grades was examined. Data from 2014 and 2015 semesters shows that classes that did not have mid-term grades released had a higher percent of unsuccessful students compared to those with mid-term grades released. Then, data from 2016 semesters shows that on average 48% of students that were failing at the mid-term were able to increase their grades to pass at the end of the semester. The usefulness of the mid-term grades for students is evident in this data. I strongly recommend that not only Calculus 1, but also all mathematics courses taught at Western Michigan University have mid-term grades released for students so that they are able to see how they are doing. Beyond that, I also recommend that all instructors use Elearning to make grades readily available for students to view. The benefits are overwhelming for the students when they have access to this information. It is clear that this is one small effort that faculty can make to help ensure the success of all students.

Time Gap

After looking at how students were placed into Calculus 1 and how they progressed through the course, it was deemed important to look at gap in knowledge of students enrolled in the course. That is, how long ago their last math class and/or placement mechanism. In order to investigate this, students were classified into three categories. The first category was no gap, which was defined as taking Calculus immediately after their previous math class. Examples include taking Pre-Calculus in the fall and then Calculus in the spring, or taking Pre-Calculus in summer II and Calculus in the fall. The second was less than 1 year, which includes students that start Calculus after their last class ended less than one calendar year ago. An example of this is

taking Pre-Calculus in the spring, and continuing with Calculus in the fall or a first year student finishing their high school math class in June when they graduate and taking Calculus in the fall. The last category was more than one year. An example of this includes a senior taking their only required math class during their last semester of college, after not taking a math class since high school, 4 years ago. Data collected is displayed below to show how many students passed or failed depending on the time gap category with which they belong.

Figure 45: Spring 2016 Female time gap compared to final grade

Length of Gap	Pass	Fail	% Fail
None	10	3	23
Less than 1 Year	6	1	14
1 or More Year	5	0	0

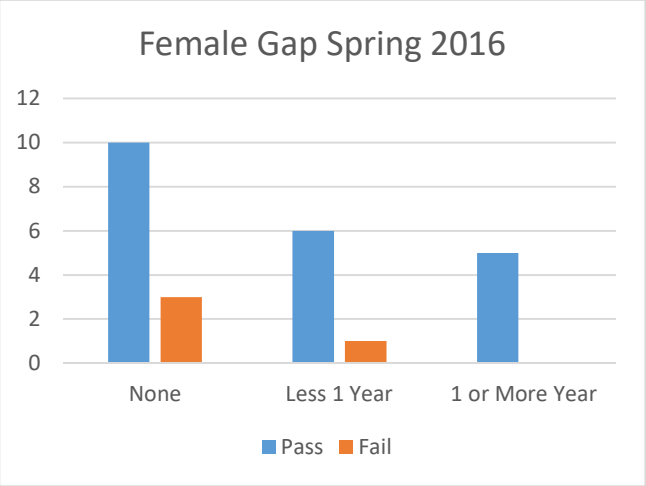


Figure 46: Spring 2016 Male time gap compared to final grade

Length of Gap	Pass	Fail	% Fail
None	40	12	23
Less than 1 Year	7	10	59
1 or More Year	23	19	45

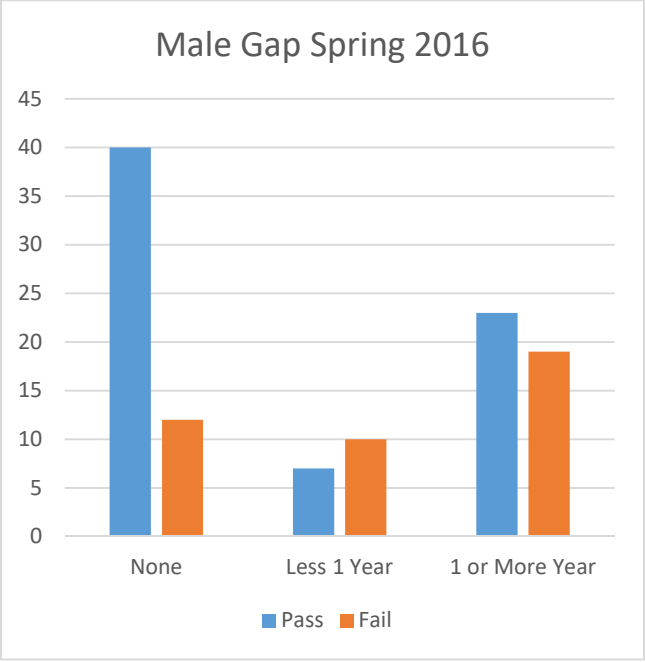


Figure 47: Spring 2016 Combined time gap compared to final grade

Length of Gap	Pass	Fail	% Fail
None	50	15	23
Less than 1 Year	13	11	46
1 or More Year	28	19	40

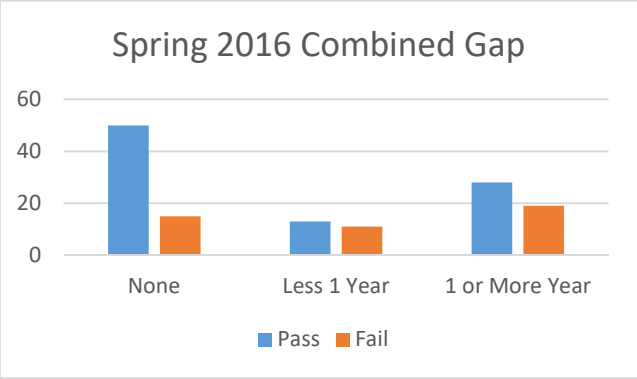


Figure 48: Fall 2016 Female time gap compared to final grade

Length of Gap	Pass	Fail	% Fail
None	1	0	0
Less than 1 Year	21	1	5
1 or More Year	9	0	0

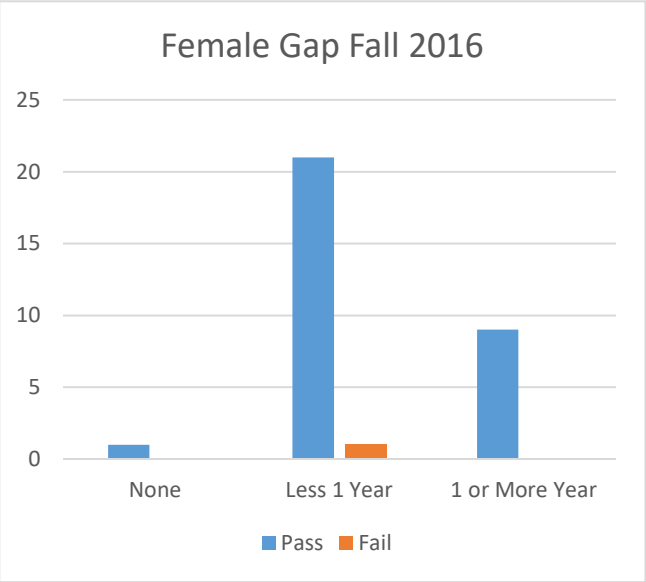


Figure 49: Fall 2016 Male time gap compared to final grade

Length of Gap	Pass	Fail	% Fail
None	4	0	0
Less than 1 Year	61	8	12
1 or More Year	34	10	23

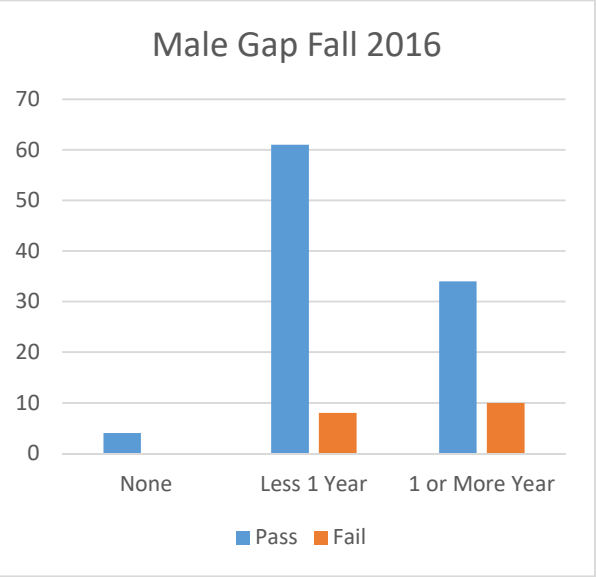
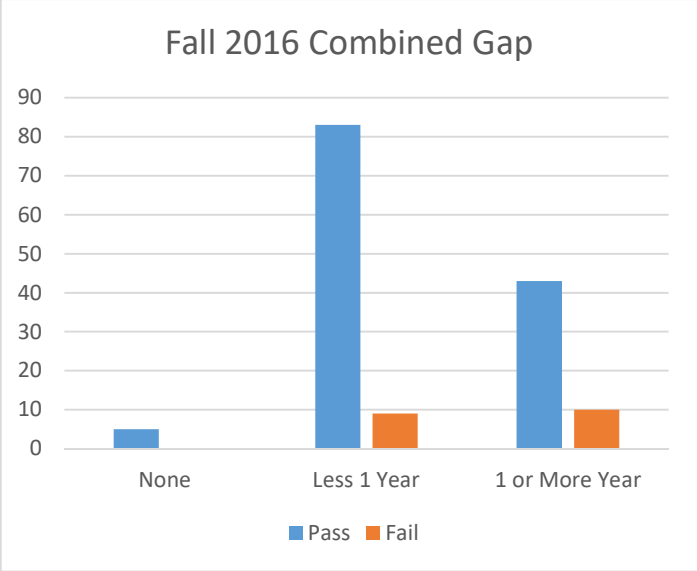


Figure 50: Fall 2016 Combined time gap compared to final grade

Length of Gap	Pass	Fail	% Fail
None	5	0	0
Less than 1 Year	83	9	10
1 or More Year	43	10	19



Based on the data, one can see that the longer students wait in between taking their math courses, the more they will struggle in the course. Figures 47 and 50 both show very high passing rates for students that have no gap in between their math courses. This makes sense, as the Prerequisite knowledge that is essential to be successful in the course will be fresh in their minds. When we look at less than one year, we start to see more students not being successful in the course. In fact, Figure 46 shows that more males were unsuccessful in the course than were successful. Finally, for more than one year, Figure 46 also shows that only four more students were successful than those that were unsuccessful in Calculus 1 for that semester. This data shows the development of a trend that students with smaller time gaps perform better. In fact, some of the students that were unsuccessful that fell into the one or more year category have some of the lowest initial assessment and mastery 1 scores. Below are tables that show this trend.

Figure 51: Comparison of Time Gaps to Mastery 1 and Initial Assessment Averages

Mastery 1 Averages			
Spring 2016	Males (%)	Females (%)	Combined (%)
No Gap	77.5	76.6	77.34
Less 1 Year	70.8	80.4	72.53
1 or More Year	60.3	73.2	62.62

Mastery 1 Averages			
Fall 2016	Males (%)	Females (%)	Combined (%)
No Gap	48	19	41.92
Less 1 Year	59	65.1	60.28
1 or More Year	46.2	52	47.42

Initial Assessment Averages			
Spring 2016	Males (%)	Females (%)	Combined (%)
No Gap	54.3	57.6	54.89
Less 1 Year	49.2	54.7	50.19
1 or More Year	46.4	50.9	38.05

Initial Assessment Averages			
Fall 2016	Males (%)	Females (%)	Combined (%)
No Gap	48	42	46.74
Less 1 Year	52.5	53.6	52.73
1 or More Year	45.7	42.5	45.03

Figure 51 shows that for both the mastery 1 and the initial assessment, the students that fell into the "1 or more year" category scored on average the lowest scores. These students tend to struggle to be successful in Calculus 1.

Overall, I feel that this is an area that needs attention. I am recommending that advisers from both the math department and academic colleges work with incoming first year students when they register for classes and encourage them to take their math classes as soon as possible.

First year students need to understand that the longer they wait, the more likely they are to be unsuccessful in their math course.

Conclusions

Overall, many factors can contribute to either the success or failure of students that enroll in Calculus 1. Figure 1 shows us that gender is not a clear-cut indicator of success. There are not enough female students enrolled in Calculus 1 in order to get reliable data. The low enrollment numbers are easily influenced, and show no clear trends. From the available data, one can see that for the most part females do tend to have a lower failure rate than the males. In five of the six semesters examined, females had a better passing percentage than the males. While this can be extrapolated from the data, it is important to note that with more data from more semesters, different trends may emerge. Since there were a significantly more number of male students enrolled in Calculus 1, more data could be examined. For males, failure rates remained relatively steady and then started to decrease as a direct result of new course coordination. Beyond gender, ethnicity is a good indicator of success or failure. Figure 2 shows certain minority populations, such as Blacks and Hispanics that have high failure rates compared to those of White students. While support services exist for all Western Michigan University students free of charge, not all students take advantage of them. The data shows that our minority students are at the greatest risk of not being successful in Calculus 1. The team of instructors need to make a consistent push for students to visit and take advantage of these resources. In addition, members of the support centers can send a representative to talk to students about services offered, especially minority students. If the math department continues to have Learning Assistants in each section of Calculus 1, these Learning Assistants need to continue to be vocal about resources that are available for their students.

When it comes to being placed into Calculus 1, some change is needed. Figures 5 and 8 show the success rates of students based on their Pre-Calculus grades. The higher score attained in Pre-Calculus, the better chance of success in Calculus 1. However, there are still students earning A's, as noted in Figure 5 that are not successful in Calculus. In addition, Figures 5 and 8 both indicate students earning a "C", which is considered sufficient to continue to Calculus 1, have an equal chance of success or failure. If that grade from Pre-Calculus is deemed adequate for students to move on, but only around 50% are actually successful, then maybe they should not be able to move on in the math sequence with a grade of a "C". It is important to note that these could be results of different instructors teaching a course that has been un-coordinated until spring 2017. Once students the earned passing grades in Pre-Calculus under the new coordination complete Calculus 1, we will have a clearer picture of their chances of success.

Another placement method used are ACT scores. Currently, students need to earn at least a 27 on the math section to place directly into Calculus 1. Figures 11 and 14 show that these scores are appropriate, and are a good indicator of success and seem to place students adequately well. Students that were placed by this method actually had a better chance of passing than if Pre-Calculus scores placed them. For example, Figure 8 shows that 81% of students placed by Pre-Calculus scores in the fall of 2016 were successful compared to the 94% placed by ACT scores. Therefore, there is a clear trend that students placed by ACT scores are being properly placed.

Finally, advisor overrides are also used to place students into Calculus 1. Figures 15 and 16 show the data for students placed by this method. The math department needs to work to decrease the number of students placed this way. The other methods are based on readiness standards. If students do not meet these standards, then they are most likely not ready for the

rigor of Calculus 1. While special circumstances may exist for certain students, I believe that these students should be required to demonstrate readiness in order to get the advisor override. I hope that this can help to decrease the number of students incorrectly placed by this method, and the number of unsuccessful students placed by this method. However, the idea of how to work with adviser overrides could be the topic of a further investigation and is beyond the scope of this investigation.

When the progression of the students was examined, there were clear indicators of success and failure. Due to the initial assessment not being taken in a proctored environment, the data is unreliable to predict success. In order for the data to be reliable to predict success, these assessments could be taken in a proctored environment. This could also be a topic of another investigation, and as it is beyond the scope of this investigation. Mastery 1 and Mastery 2 exams are both given in proctored environments, so their data is reliable to predict success. Figures 25 and 28 for spring and fall mastery 1 and Figures 31 and 34 for spring and fall mastery 2 data show how higher scores can help to predict success in the course. Instructors need to examine this data as soon as students are finished taking these exams. Students that struggled on the exams need to be aware of where they stand, and what resources are available to them. In addition to these exams, mid-term grades are extremely important. Figures 41 and 44 both show how mid-term grades can have an effect on student success. Almost every student that was passing at the time mid-term grades were released ended up passing the course for credit. For the students that were not passing at the mid-term, about half each semester were able to overcome their challenges and pass the course for credit. The impact on having the grades made available to them is clear, as one can see that many students were able to improve their course grade after their mid-term grade was released. . In addition, Figures 35, 36, 37, and 38 also show that on

average classes that did not have mid-term grades released averaged a higher rate of students unsuccessful in the course. Currently all Calculus 1 instructors are required to release mid-term grades. However, I believe that this should be extended to all mathematics instructors. Students should be aware of their status in a class, and this is a great indicator of their status, and if they should continue or consider withdrawing from the course.

Finally, gaps between mathematics courses can be detrimental to the success of students. The longer students wait between taking courses, the more information they will not retain that will be crucial to their success in the course. Figures 47 and 50 show these trends. Students will no gap had the best chances of success, and then students will gaps in-between classes. The university as a whole needs to work to encourage students to take courses without gaps, as well as to take required math courses as soon as possible, if only one math course is required for their degree.

Overall, since new coordination began in spring of 2016, students enrolled in Calculus 1 have been more successful than in previous semesters. The changes in instruction and the mastery exams may be important to their success. Now, the team of instructors need to work to utilize this information available to them for the benefit of their students. Placement and the mastery exams are the best predictors that can be used to predict success in the course. If we want to maintain and even improve the success rates of our students, instructors need to utilize the information available to them from theses exams to better help their students be successful.

Works Cited

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