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# APPLIED CALCULUS AND GATEWAY ASSESSMENTS

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## **Applied Calculus and Gateway Assessments**

### **Synopsis:**

Applied Calculus draws a large number of non-majors with widely varying mathematical backgrounds. In the past students often completed Applied Calculus without a mastery of basic calculus skills. The implementation of gateway assessments has alleviated this problem, however the implementation has been challenging with over 1000 students enrolling in the course each year. We look at the implementation of gateway assessments over the past few years at West Virginia University.

# Applied Calculus and Gateway Assessments

*In this paper, we discuss our experience with the implementation of high stakes gateway assessments in a large enrollment course, Applied Calculus. Ways in which to implement gateway assessments with or without technology are discussed in this paper as well as data that shows students' achievement on the assessed topics. We also discuss some of the changes we have made over the years and share our experiences of best practices. We have found that almost every student ultimately passes the gateway assessments, and our failure rates in the courses have not been affected. Less than .5% of students fail to pass the course solely as a result of the gateway.*

## **Introduction**

We are very proud of the Applied Calculus course at our university. The course is designed primarily for business majors and includes other majors (discussed below). We take an applications first approach in lecturing, labs, and exams. Exams for the course are almost exclusively application problems with very little or no skill based questions. Because of this, we have given two gateway assessments on differentiation and indefinite integration skills. The format and structure of these have varied over the years, but the goal has been the same – to master the skills in calculus and then use those skills within real world applications in lecture, labs, and exams.

Over numerous years of teaching, we noticed that many students were passing our course (or coming very close to passing the course) without having a strong understanding of some of the basic, fundamental skills in an introductory calculus course. To address this problem, we introduced gateway assessments that were designed to require students to master these

fundamental topics. In this paper, we discuss the ways in which we have implemented these gateway assessments in Applied Calculus.

At our university, Applied Calculus is a three-credit course, taught in sections of 80 to 100 students, with 2.5 hours of class time each week held in a lecture style classroom and 50 minutes of lab time each week held in a computer center. Twice each semester, gateway assessments are given online during this lab time. Gateway assessments for this course are conducted using the same online program students use for homework, lab, and exams. We present our use of gateways in this paper to show methods that can be implemented with access to technology and showcase what we have done in hopes that the readers will be able to find ideas that would work within their own course structure.

Currently in Applied Calculus, we administer two gateway assessments throughout the semester. The first focuses on calculating derivatives, while the second focuses on calculating indefinite integrals. Both assessments are completely skill based and consist of 10 questions which are administered via an online system and graded as correct or incorrect (no partial credit is given). Students must score an 80% or better on an attempt of each gateway assessment in order to earn a passing grade in the course, as determined by the breakdown in the course syllabus. This includes points for exams, quizzes, homework assignments, and online laboratories. If a student fails to meet both gateway score requirements, they are not permitted to receive a passing grade in the course, a C- or higher. The reader will notice that all data relevant to these and previous gateway assessments is from fall semesters. This is to ensure comparable student populations.

## **Applied Calculus Course Structure**

Applied calculus is a course targeting primarily business, exercise physiology, pre-pharmacy, and forestry majors, with the majority of students being business majors, approximately 70%. It is a terminal math course for these majors. It serves 500-700 students per semester, in class and lab sizes of approximately 80 to 100 students. This calculus course is less traditional since it is heavily focused on applying functions, derivatives, and integrals to real-world scenarios. The content is split into three units: using functions as models and modeling techniques used in solving real world problems, using the derivative as a tool to solve application based problems involving rates of change, and using the definite integral and area to solve real world problems involving accumulation. One portion of the course involves two 75-minute lectures per week. This course also incorporates computer-based laboratories for one 50-minute class per week, specifically designed to emphasize the connection of mathematical concepts to real-world scenarios. This lab time is used for regular exams and gateways as well.

## **History of Gateway Assessments in Applied Calculus**

### **Pre-2011**

Prior to Fall 2011, under different course administration, two gateway assessments were given in the Applied Calculus course. These were also for the same topics: differentiation and indefinite integration rules. The format of class meetings (Tuesday, Thursday 75 minute lecture; Wednesday 50 minute lab) was the same. Students were given gateways on paper during their lab time. Calculator use was permitted with some restrictions. The gateways consisted of eight problems with formulaic answers and two numeric computations. Lab assistants graded these. One retake was given and the higher score counted. A formula sheet was provided (similar to those today, shown in the Appendix). Each gateway counted as five percent of the overall grade. Most semesters, students were allowed two attempts (sometimes this was contingent on class

attendance record), and the higher score counted. Minimum scores were not required, and many students passed the course without showing proficiency in these areas.

<b>PERCENT OF PASSING STUDENTS NOT MEETING MINIMUM COMPETENCY SCORE (80%)</b>		
<b>Semester</b>	<b>Derivatives</b>	<b>Integrals</b>
<b>Fall 2009 (2 Attempts, no min. score)</b>	30.7%	38.9%
<b>Fall 2010 (2 Attempts, no min. score)</b>	26.1%	41.7%

About 25-30% of students who passed the course did not show mastery of differentiation skills. Around 40% did not show mastery of indefinite integration. In most cases, these students were able to pass the course because of the focus on applications and calculator use on regular exams, homework, and lab assignments.

### **Fall 2011-Spring 2013**

Starting in the Fall 2011 semester with the current course administration, we decided to attempt to fix the problem of students passing Applied Calculus without demonstrating competency in the basic calculus skills of differentiation and indefinite integration. We changed the administration of gateways so that they were online. They became ten problems each, all with formulaic answers. Calculators were no longer permitted, but we still allowed a formula sheet.

The scores on the gateways did not factor into the overall grade in the course. Students were required to earn an 80% or higher on each gateway in order to pass the course with a C- or

higher. Multiple attempts were given, with the computer system regenerating each gateway from a large pool of questions. All students passing Applied Calculus were now ensured to demonstrate minimum competency in these skills before passing the course.

While this approach solved the initial problem, many new challenges ensued. Instructors would facilitate any necessary retakes for students and some students took gateways more than 10 times. With each section of the course having 80 or more students and many instructors teaching more than one section, this was very difficult to manage. Students appeared to be less motivated to adequately prepare for the initial attempt, knowing they would receive multiple retakes. We noticed the volume of students with this problem seemed to increase in subsequent semesters.

### **Fall 2013-Present**

Because of these issues, we implemented several changes for the Fall 2013 semester. Most of these have remained constant through the current semester. We adopted the previous format of an online assessment with ten questions, no calculator, and use of a provided formula sheet. The score on the gateway was again factored into the overall grade and the minimum 80% score was required for a passing grade in the course. At first, we allowed the highest score to count and to meet the minimum competency requirement. Since Fall 2015, only the first score has counted toward the student's overall grade. Any additional attempts are only used to meet the minimum competency requirement. This seems to have improved motivation and scores on the first attempt. As shown below, the percentage of students passing during the first week of administration and on the first attempt of each gateway has steadily increased. Outliers involve changes to the schedule, not allowing in class review due to Election Day. In the current setup (since 2015), approximately 80% of students pass the Derivatives Gateway during the first week

(65% pass the first attempt), and approximately 70% of students pass the Integrals Gateway during the first week (60% pass the first attempt).

#### PERCENT PASSING FIRST WEEK

Semester	Derivatives	Integrals
Fall 2012	77.1% (Four Attempts)	67.2% (Four Attempts)
Fall 2013	74.1% (Two Attempts)	71.3% (Three Attempts)
Fall 2014	76.2% (Three Attempts)	71.3% (Three Attempts)
Fall 2015	82.9% (Three Attempts)	72.6% (Three Attempts)
Fall 2016	82.7% (Three Attempts)	63.8% (Three Attempts)
Fall 2017	78.2% (Two Attempts)	81.5% (Three Attempts)

#### PERCENT PASSING FIRST ATTEMPT

Semester	Derivatives	Integrals
Fall 2012	62.0%	46.5%
Fall 2013	51.0%	43.0%
Fall 2014	49.7%	36.0%
Fall 2015	61.9%	63.5%
Fall 2016	66.0%	47.0%
Fall 2017	67.7%	59.1%

A policy sheet has been developed (See Appendix) for each gateway, explaining the requirements of the students and rules for earning additional attempts. This policy sheet was developed in Fall 2014. It remains largely the same from semester to semester. Small changes are made to accommodate facilities, instructor and teaching assistant needs.

### Current Gateway Assessments

#### Preparation

First, two class days are spent covering the skills needed for each respective gateway. For derivatives, we spend the first day covering the basic derivative rules and properties: power, exponential, and logarithmic rules with sum/difference and constant multiple properties. The second day is spent learning product, quotient, and chain rules. For integrals, the first day is spent covering the basic integral rules and properties: power, exponential, and logarithmic rules with sum/difference and constant multiple properties. The second day is spent learning

integration by substitution. Students have required online homework assignments to prepare them for the gateway, which are administered in the same online system. If the schedule permits, we have an extra review day in class for the students the day before the gateway exam. Typically, gateway skills are taught on Tuesday and Thursday lectures. The following Tuesday lecture is allocated for review and students receive their initial gateway assessment on the following day, Wednesday, in lab.

### **Initial Attempts**

Students take the first attempt of the gateway exam during their scheduled computer laboratory time. They are not permitted any calculator use and are not required to simplify their answers. They are allowed a formula sheet (See Appendix). As stated earlier, students use an online system (their online homework and examination system) to take the assessment. The online system allows us to pool questions, so that each assessment varies, but contains similar types of questions. Also, with question pooling, a consistent distribution of question difficulty is guaranteed, ensuring fairness among students and among each attempt. Students are permitted only one attempt of the assessment during the 50 minute laboratory time.

### **Additional Attempts**

Any student who does not pass the gateway during the first laboratory day must retake the assessment until he or she achieves the minimum competency score of at least 80%. Over the semesters, we have changed our process on retakes of the gateway. Currently, if the student does not pass the first day, we hold an additional day of retakes, outside of scheduled class and lab time, later that week (usually Thursday), and each student is given the opportunity for an additional attempt. If the student still fails to pass the gateway, a student must “earn” additional

opportunities for attempts with the completion of two short quizzes using the same online assessment system.

These short quizzes must be taken over the following seven days and completed with a minimum score of 90% on each quiz. Students are afforded an unrestricted number of attempts in a lab room during allotted times. These quizzes must be completed in a testing environment. This means the quizzes are password protected, proctored, and no use of notes or calculators are permitted. These quizzes are structured to mimic the actual gateway assessments in form and environment. To balance this relatively high risk environment, practice versions of these quizzes are accessible by students online at home as well.

We then offer two more days the following week when the gateway can be taken outside of class time. Again, only one attempt of the assessment is permitted per day. If the student still fails to pass the gateway after these attempts, they must meet with their instructor individually and the instructor will determine how and when the student will be able to earn other attempts. In addition to requiring a 90% on both online assignments, an instructor may review past attempts with the student, create additional problems for them to practice, and try to help the student with any problems he or she is having.

## **Summary**

Based on experience in our Applied Calculus course over the past ten years or more, we have concluded that gateway assessments are very worthwhile in ensuring that the students meet the goals of the course. The first gateway focuses on calculating derivatives, while the second focuses on calculating indefinite integrals. Both assessments are completely skill based and consist of 10 questions, which are administered via an online system and graded as correct or incorrect (no partial credit is given). Students must score an 80% or better on an attempt of each

gateway assessment in order to earn a passing grade in the course. Based on data over the past ten years, we have adjusted the implementation and scoring of gateway assessments and additional attempts of these assessments. We currently have a system ensuring that students passing Applied Calculus reach minimum competency in essential calculus skills. The vast majority of students achieve this requirement. While instructors do have additional workload beyond the traditional expectation for such a course because of these assessments, improvements have been made to streamline the process and make it very manageable. In the future, we hope to continue to monitor data on these assessments and refine our procedures to ensure the success of our gateways. We also hope that other instructors find usefulness in our work and are able to use it to help meet the goals of their own courses.

# Appendix

## Most Recent Policy Sheets

### MATH 150 SPRING 2018 DERIVATIVE GATEWAY PROCEDURE

The derivative gateway consists of skill exercises focused on differentiation.

Conditions for the gateway:

- 10 problems on MyLabsPlus: given  $f(x)$ , find  $f'(x)$
- Closed books/notes
- Calculators are NOT permitted
- Formula sheet IS permitted and provided
- A minimum score of 80% is REQUIRED in order to receive a passing grade in the course.
- Your score on ATTEMPT 1 (during lab on Wednesday 2/14) counts as 5% of your overall grade in the course. Later attempts DO NOT count in the overall grade.

ATTEMPT 1: Wednesday, February 14<sup>th</sup> during your scheduled lab time in Armstrong Hall.

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If you do not earn an 80% on the attempt in lab on Wednesday, February 14<sup>th</sup>, you may choose to attend an additional attempt.

ATTEMPT 2: Thursday, February 15<sup>th</sup> 5:30-7:30 in 215 Armstrong.

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If you have not received an 80% by the end of Thursday, February 15<sup>th</sup>, you can **earn** two more attempts the following week by earning minimum scores on two quizzes: Short Quiz 1 and Short Quiz 2. The deadline for these quizzes is 5:30 PM, Thursday, February 22<sup>nd</sup>.

Conditions for each quiz:

- Must be completed in the lab in 215 Armstrong during open lab hours.
- Closed books/notes.
- Calculators are NOT permitted.
- Unlimited attempts until 5:30 PM on Thursday, February 22<sup>nd</sup>.
- Formula sheet IS permitted and provided.
- Derivatives Gateway Short Quiz 1 must have a score of 90% or better.
- Derivatives Gateway Short Quiz 2 must have a score of 90% or better.
- Quizzes and Attempts follow the Academic Integrity Policy.

If you meet the conditions above, you can have two additional attempts:

ATTEMPT 3: Wednesday, February 21<sup>st</sup>, 5:30-7:30 in 215 Armstrong.

ATTEMPT 4: Thursday, February 22<sup>nd</sup>, 5:30-7:30 in 215 Armstrong.

**\*\*\*Attempts do not bank. If you do not take an attempt during its correct time, you may not take that attempt later.**

Attempt 4 is the last guaranteed attempt. If you have not passed by the end of Attempt 4, you may choose to attend one final retake at the end of the semester. Dates and times will be announced at a later date.

# MATH 150 SPRING 2018

## INTEGRAL GATEWAY PROCEDURE

The integral gateway consists of skill exercises focused on integration.

Conditions for the gateway:

- 10 problems on MyLabsPlus: find  $\int f(x)dx$
- Closed books/notes
- Calculators are NOT permitted
- Formula sheet IS permitted and provided
- A minimum score of 80% is REQUIRED in order to receive a passing grade in the course.
- Your score on ATTEMPT 1 (during lab on Wednesday, April 4<sup>th</sup>) counts as 5% of your overall grade in the course.

ATTEMPT 1: Wednesday, April 4<sup>th</sup> during lab time in 421 Armstrong.

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If you do not earn an 80% on the attempt in lab on Wednesday, April 4<sup>th</sup>, you may choose to attend one additional attempt.

ATTEMPT 2: Thursday, April 5<sup>th</sup> 5:30-7:00 in 421 Armstrong.

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IF you have not received an 80% by the end of Thursday, April 5<sup>th</sup>, you can **earn** two more attempts by earning minimum scores on two preparatory quizzes. In order to earn these attempts, you must complete two short preparatory quizzes (details below), you must attend your lab time on Wednesday, April 11<sup>th</sup>, and complete a lab check-in. You must have completed all of these requirements before starting Attempt 3 or 4.

Conditions for each quiz:

- Must be completed in the lab in 215 Armstrong during open lab hours Monday, Tuesday, Wednesday or Thursday, April 9-12.
- Closed books/notes.
- Calculators are NOT permitted.
- Unlimited attempts until close of lab on Thursday, April 12<sup>th</sup>.
- Formula sheet IS permitted and provided.
- Integral Gateway Short Quiz 1 must have a score of 90% or better.
- Integral Gateway Short Quiz 2 must have a score of 90% or better.

IF you meet the conditions above, you can have two additional attempts.

ATTEMPT 3: Wednesday, April 11<sup>th</sup>, during lab time.

ATTEMPT 4: Thursday, April 12<sup>th</sup> 5:30-7:00 in 421 Armstrong.

**\*\*\*Attempts do not bank. If you do not take an attempt during its correct time, you may not take that attempt later.**

If you have not passed by the end of Attempt 4, you may choose to attend one final retake at the end of the semester. Dates and times will be announced at a later date.

## Formula Sheets

# MATH 150 DERIVATIVES GATEWAY FORMULA SHEET

### POWER RULE

$$f(x) = x^n$$
$$f'(x) = nx^{n-1}$$

### EXPONENTIAL RULES

$$f(x) = e^x \qquad f(x) = a^x$$
$$f'(x) = e^x \qquad f'(x) = (\ln a)a^x$$

### LOGARITHM RULE

$$f(x) = \ln x$$
$$f'(x) = \frac{1}{x}$$

### SUM/DIFFERENCE RULES

$$\frac{d}{dx}[f(x) + g(x)] = f'(x) + g'(x)$$
$$\frac{d}{dx}[f(x) - g(x)] = f'(x) - g'(x)$$

### EXPONENT RULES

$$x^{-n} = \frac{1}{x^n}$$
$$x^{m/n} = \sqrt[n]{x^m} = \left(\sqrt[n]{x}\right)^m$$

### CONSTANT MULTIPLE RULE

$$\frac{d}{dx}[k \cdot f(x)] = k \cdot f'(x)$$

### PRODUCT RULE

$$\frac{d}{dx}[F(x) \cdot G(x)] = F'(x)G(x) + F(x)G'(x)$$

### QUOTIENT RULE

$$\frac{d}{dx}\left[\frac{F(x)}{G(x)}\right] = \frac{F'(x)G(x) - F(x)G'(x)}{[G(x)]^2}$$

### CHAIN RULE

$$\frac{d}{dx}[f(g(x))] = f'(g(x)) \cdot g'(x)$$

# MATH 150 – INTEGRALS GATEWAY

## FORMULA SHEET

### INTEGRALS

$$\int x^n dx = \frac{1}{n+1} x^{n+1} + C \text{ if } n \neq -1$$

$$\int [f(x) + g(x)] dx = \int f(x) dx + \int g(x) dx$$

$$\int x^{-1} dx = \ln|x| + C \quad \text{OR} \quad \int \frac{1}{x} dx = \ln|x| + C$$

$$\int kf(x) = k \int f(x) dx$$

$$\int e^x dx = e^x + C$$

### DERIVATIVES

#### POWER RULE

$$f(x) = x^n$$
$$f'(x) = nx^{n-1}$$

#### CONSTANT MULTIPLE RULE

$$\frac{d}{dx}[k \cdot f(x)] = k \cdot f'(x)$$

#### EXPONENTIAL RULES

$$f(x) = e^x \quad f(x) = a^x$$
$$f'(x) = e^x \quad f'(x) = (\ln a)a^x$$

#### PRODUCT RULE

$$\frac{d}{dx}[F(x) \cdot G(x)] = F'(x)G(x) + F(x)G'(x)$$

#### LOGARITHM RULE

$$f(x) = \ln x$$
$$f'(x) = \frac{1}{x}$$

#### QUOTIENT RULE

$$\frac{d}{dx} \left[ \frac{F(x)}{G(x)} \right] = \frac{F'(x)G(x) - F(x)G'(x)}{[G(x)]^2}$$

#### SUM/DIFFERENCE RULES

$$\frac{d}{dx}[f(x) + g(x)] = f'(x) + g'(x)$$

$$\frac{d}{dx}[f(x) - g(x)] = f'(x) - g'(x)$$

#### CHAIN RULE

$$\frac{d}{dx}[f(g(x))] = f'(g(x)) \cdot g'(x)$$

### ALGEBRA

$$x^{-n} = \frac{1}{x^n}$$

$$x^{m/n} = \sqrt[n]{x^m} = \left(\sqrt[n]{x}\right)^m$$