Course Syllabus

Site: Rose-Hulman Institute of Technology
Course: 2122W MA483
Book: Course Syllabus

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Table of contents

MA483 Bayesian Data Analysis

Course Description:

This course offers an introduction to inference (making statements about a population of interest using a sample from the population) under the Bayesian framework. Building from Bayes' Rule for probability computations, we develop a framework of estimation and hypothesis testing. We will examine inference in several scenarios, including regression analysis. We discuss the construction of prior distributions given prior information about a parameter and give an introduction to computational tools for Bayesian inference, including Markov Chain Monte Carlo (MCMC) methods.

Learning Objectives:

As in any statistics course, we emphasize statistical literacy (interpretation and clear communication of statistical methods, results, and concepts) and statistical reasoning (modeling variability in a process, defining the need for data to address questions, choosing appropriate methodology, and critiquing an analysis). Specifically, after completing this course, students will be able to accomplish the following tasks:

(A) Given a research goal, **identify** the parameter(s) of interest and, if applicable, **formulate** the goal as measurable statements about the parameter(s) of interest.

(B) **Describe** the importance of considering data collection when interpreting the results of a study. Specifically, **determine** whether it is reasonable that a sample is representative of the underlying population and **justify** your rationale.

(C) **Construct** and **interpret** graphical and numerical summaries of data to address a research goal.

(D) Given a description of the data generating process, **construct** a probability model that represents that process as a function of unknown parameters.

(E) Given a question of interest, **construct** a probability distribution that captures the information on the parameter prior to conducting the study, and use the data to **update** the information on the parameter.

(F) **Comment** on the adequacy of a statistical method for addressing a given question of interest by **assessing** the assumptions underlying the method.

(G) Given a posterior distribution, **summarize** the uncertainty in the parameter of interest and **interpret** the resulting output in context of the research question.

(H) **Identify** the value of statistical methodology in the advancement of science as well as **recognize** its limitations.

(I) Clearly **communicate** an analysis and its implications in written format.

(J) **Describe** the role of probability theory in the Bayesian framework for making inference on a population and **appreciate** the use of probability for capturing uncertainty about a parameter and the use of data to inform that uncertainty.

Course Prerequisites

MA381 (Introduction to Probability), or an equivalent, is a prerequisite for this course. We will rely heavily on probability theory throughout the course, and it is expected that you have a very good grasp on the material from MA381. For the benefit of those who have taken other courses in statistics (MA223, MA382, MA386, MA481, MA482, MA485), we will compare the framework in this class to those discussed there; however, exposure to this material is not required or assumed. Competency in a computing language is beneficial.

Contact Information

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Contacting the Instructor:
I do not have regular office hours dedicated to this class. If you have questions, feel free to email or message me on Teams. I keep my Outlook calendar and Teams status up to date. Alternatively, you may always email me to schedule an appointment.

While I try to be prompt with responses, I will respond to email within 1 business day. Note that this means that emails received after 5 PM (EST, Terre Haute time) will, in general, not be addressed until the following business day. I am, in general, not available of an evening (after 5 PM) or on weekends, as these times are reserved for my family.

If there will be any disruption to my availability (due to travel, for example), I will let you know.

Instructor Biography

After graduating from Rose-Hulman Institute of Technology in 2006 with a degree in Mathematics and Economics, I attended graduate school at North Carolina State University where I earned my Ph.D. in Statistics under the direction of Dr. Dennis Boos and Dr. Len Stefanski. My primary interest is biostatistics - the application of statistical methodology to medical research. As a former participant in the NHLBI Integrated Biostatistical Trainee Program for CVD Research, I spent five years as an intern at the Duke Clinical Research Institute serving as a statistical consultant under the direction of Karen Pieper.

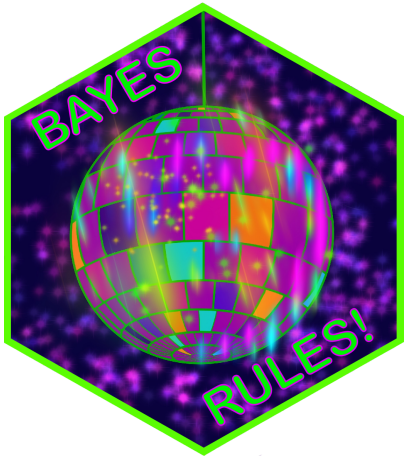
My research interests include methods for variable selection (the process of discerning which variables are useful for predicting a response) and statistics education (how to teach my discipline in a way that gives the best student learning experience).

I was hired into the math department to teach primarily statistics. I believe it is important for every student on campus to be statistically literate. In addition to teaching statistics, I am the faculty adviser for the InterVarsity Christian Fellowship chapter on campus.

Additional Textbook (Optional):

Title: Bayes Rules! An Introduction to Bayesian Modeling with R
Author: Johnson, Ott, Dogucu

This text was chosen because it provides an excellent reference for learning about Bayesian inference without assuming a familiarity with statistics or probability. For those that learn well from textbooks, this would be an excellent companion to the course. It is freely available online.



Course Notes:

The course is primarily taught from a series of instructor notes developed for this course. While the above textbook is quite good, it does not leverage your mathematical foundation (both in probability as well as programming); the course notes present material in a slightly different order with a little more mathematical rigor. However, the above book is great at explaining concepts and illustrating very difficult principles. Guided notes and video lectures will help you work through the note packet. Additional comments made during course discussions, especially in response to student questions, should be added to your personal course notes.

Course Software:

- **RStudio:** R is a freely available statistical computing language. RStudio provides a nice interface to this computing language. It is freely available; instructions for obtaining both R and RStudio will be provided.
- **rstan:** Stan is a probabilistic programming language specifically designed for Bayesian inference. The rstan packages provides an interface from R to Stan. This additional functionality is obtained if you follow the installation instructions provided for setting up the course software.

Additional Technology Requirements:

Much of the course content will be placed on the course page, requiring online access. At a minimum, you should be able to perform the following tasks *prior* to beginning the course:

- Navigate Moodle and interact with activities posted in Moodle (such as discussion forums and quizzes).
- Typeset mathematical equations using Microsoft Word or LaTeX.
- Have access to a high-speed internet connection for viewing instructional videos, downloading course note packets and data, and submitting course assignments.

You will need dependable internet access (on-campus wireless internet will be sufficient) to successfully complete this course. **If you plan to be in a location during the course that does not have reliable internet access or restricts access** of **Google products (such as Google Chrome), you may be unable to successfully complete aspects of the course.**

Un-Grading Procedures

I love my discipline; I love the idea of taking measurements and turning them into actionable decisions that can benefit others. I love finding information where others see "numbers." And, I love communicating abstract statistical concepts. That is why I became a professor - to be a part of that learning experience as people are first exposed to statistics. As a professor, I enjoy lecturing, walking through problems, and helping students resolve difficult ideas. But, too often the positive experiences are ruined by grades.

I dislike agonizing over how much credit to give for a solution instead of just pointing to ways that the solution can be improved. I dislike that students turn in subpar work because they face opposing priorities and know that they can get by with partial credit. I dislike arguing whether a problem is worth x points or x + 1 points instead of the misconception highlighted by the submitted work. I hate that grades terminate the conversation about a set of problems instead of recognizing that learning is a process. I hate that grades are a stick to get you to walk through the learning process instead of working with students who are genuinely interested in learning. I spent so much time as a student chasing a particular grade and missing so many cool discoveries I might have made. I want more for you.

As a result, this class will make use of a strategy known as *un-grading*. You will take the primary role in determining your grade in this course. Throughout the term, you will be building a case for the grade you feel reflects your learning in the course and your progress toward the course objectives. Instead of passing judgment on your work, I will be taking a different role in this course - I will provide guidelines for assessing your learning and mastery and feedback on your progress. And, I am going to do everything I can to inspire a curiosity in the topic and a desire to learn more.

All that said, the institute requires that a grade be submitted for each of you at the end of the course. And, I have a responsibility to my discipline and to the academic integrity of this institute to hold you to a minimum standard. This section outlines the process for ensuring you meet that minimum standard and determining the grade submitted to the institute.

Grade	**Requirements**
A	Represents advanced work - a competency with all course objectives such that work is generally completed independently with little guidance and which is an example for others interested in this area. • Meet requirements for a D • Complete **Portfolio** with adequate justification for this assessment
B	Represents intermediate work - a competency with a majority of the course objectives such that work is generally completed independently with only some guidance. • Meet requirements for a D • Complete **Portfolio** with adequate justification for this assessment

C	Represents novice work - the level of experience gained in a classroom setting requiring additional guidance when performing tasks covered in the course. • Meet requirements for a D • Complete **Portfolio** with adequate justification for this assessment
D	Represents a fundamental awareness of the course topics - an understanding of basic techniques and concepts from the course. • Complete 1 of the 2 Homework Assignments, each problem having been attempted in good faith, associated with the Statistical Process Module. • Complete 5 of the 6 Homework Assignments, each problem having been attempted in good faith, associated with the Statistical Process Module. • Successfully complete the Concept Check for the Statistical Process Module. • Successfully complete the Concept Check for the Bayesian Fundamentals Module.

The only assignments in the course which will be formally graded are the Concept Checks for the Statistical Process and Bayesian Fundamentals Modules. All other assignments will be assessed - feedback will be provided - but not formally graded. For assignments that are graded, each assignment will be marked as "successfully completed" or not; clear expectations will be provided for what constitutes "successful completion." While perfection is not required, be aware that expectations will demand your work meet high standards.

It is expected that at the end of the course, the student and instructor will agree on a course grade; however, if a disagreement occurs, the instructor has the final authority, and the decision will be well documented.

Description of Course Assignments

The course is broken into five modules. Each module will consist of an opportunity to demonstrate progress toward the course learning objectives. Some types of assignments accompany every module, while other assignments occur only periodically throughout the course. The assignments are described below.

Homework Assignments

Homework Assignments will be assigned following each class discussion. Each assignment will consist of two problems - one generally focusing on a more conceptual topic and the other focusing on a derivation/computation. You are encouraged to consult any course resource available to you on Moodle (and personal notes) when working on the assignment as well as other students; however, each student must submit a unique assignment. If you choose to work with another student, be sure to review the Guide to Appropriate Collaboration. Each assignment will be open for at least 48 hours and will due by 11:59 PM on its due date. Each assignment will be considered complete if

- It is submitted by the due date.
- Every problem has been attempted in good faith.

Here "good faith" means that, in the judgment of the instructor, the solution attempts to answer the question asked using content from the course. Only assignments submitted by the due date are guaranteed to receive feedback.

Concept Check

A *Concept Check* will follow each module. These assignments provide an opportunity to demonstrate mastery of both concepts and analytical skills within the context of real scenarios. The due date for the assignment will be listed within the assignment; it is due by 11:59 PM on its due date. While you may consult any course resource available to you on Moodle (and personal notes) when working on the assignment, these are *individual* assignments, meaning collaboration with other students is strictly prohibited. Guidelines for characterizing good solutions will be provided with each problem on this assignment; for assignments that are graded, clear expectations will be provided defining a "successful completion." Only assignments submitted by the due date are guaranteed to receive feedback.

Portfolio

The ***Portfolio*** is the primary mechanism for students to demonstrate their learning in the course and their mastery of the course learning objectives. This assignment allows students to reflect on the course and recommend a grade based on the above descriptions and their work in the course. This document will form the basis of a review with the instructor at which time a grade for the course will be determined.

Expecting the Unexpected

Life happens; despite our planning efforts, it is inevitable that we will encounter circumstances we could not have foreseen. Learning is a process, one which extends beyond a series of assignments. For those seeking to demonstrate a mastery beyond foundational knowledge (a grade above a D), there is natural flexibility built into this course that may not exist with other classes. However, sustained learning is still the goal. The best way to ensure your work reflects sustained growth is to begin assignments promptly, refer to the guidelines for satisfactory work often, and engage with the material regularly. In addition, clear communication with the instructor is critical. Reach out to discuss any situations which are impacting your learning experience in the course.

The course policies are meant to encourage that you learn from mistakes while holding you to high standards. Those who abuse these policies will find it difficult to justify their sustained learning at the end of the course.

Academic Misconduct Penalty

Expectations for upholding academic integrity, and the importance of academic integrity within the institution, as well as the departmental policy on academic integrity, can be located in the last chapter of the course syllabus (Institute Policies). In this section, we simply outline the penalty for academic misconduct. If a student commits academic misconduct on an assignment, the following action will be taken by the instructor:

- A letter will be sent to the student, the Head of the Department of Mathematics, and the Dean of Students outlining the incident and the penalty applied.
- If the misconduct occurs on a Homework Assignment, the student forfeits the right to successfully complete the assignment.
- If the misconduct occurs on a Concept Check, the student forfeits the right to use any material from that assessment in their **Portfolio**.
- The maximum grade a student can advocate for is a C in the course.

This policy is consistent with the **Mathematics Department's Academic Integrity Policy**. To ensure you are not found in violation of the standards of academic integrity, you are encouraged to read the **Student Handbook**. Further, you should familiarize yourself with the Guide to Appropriate Collaboration.

Attendance Policy

With a course that has a remote component, it is important that you shift from thinking of "being in class" as your goal and instead "engaging with course content." All aspects of the course have been designed for remote engagement. If at some point you find yourself unable to engage in the course content, you should speak with the instructor immediately. Note: while some disruption to online services might be expected, it is also expected that you have regular access to course content at all times during the term.

In a course that includes a remote learning environment, the key to success is regular engagement with course material, and that is accomplished through remaining disciplined with your schedule. Here are the biggest lies you can tell yourself about this course:

1. *I can get everything done over the weekend*. The truth is that you might get the work done, but you most likely will not retain it well enough to perform adequately on course assessments. Learning is a process that requires regular activity; it is not a passive activity. If you do not take an active role, you will most likely find yourself saying "I understand it when you say it, but I just make 'small' mistakes on the assignments." Often, those "small" mistakes are actually large conceptual errors.
2. *I need to be perfect the first time*. Learning necessarily requires feedback; that means you will make mistakes and receive corrections to help you adjust your path forward. It is okay to make mistakes provided they come with effort. This grading system is meant to reward progress.
3. *It doesn't matter how I get there*. Learning is the process of developing mastery. That happens over time, and it is expected that you will progress toward mastery; sustained growth and effort means the material will remain - that is substantially different than cramming and demonstrating a skill at a single moment in time which often means the material is lost before the grades are finalized.
4. *I just need examples*. Learning is not pattern recognition. While this course builds on mathematical topics, it is not a mathematics course; if you have relied on patterns to learn, that will not work in this course. Certainly there are procedures we follow, but much like a humanities course, you will spend as much time explaining your logic and discovering the subtleties in others' logic than making routine computations. That is, you cannot learn the material by seeing several examples and mimicking that approach. Success requires you to spend time outside of the homework thinking about the concepts - drawing connections, being able to explain them in different ways, and recognizing them in the description of a study design. Think of it like preparing for an exam over a book you read; you want to know the plot, how the characters connect, what the story is trying to illustrate, and even how it relates to your personal narrative. Success in a statistics course is similar. If you only pay attention to the "examples," things will not go well; instead, what is the idea the example is illustrating? Knowing that will help.

At a minimum, you will be expected, *each week*, to put 3 hours into notes/lectures, an additional hour on learning activities, 3-4 hours on weekly assignments. Each student has different commitments during the term. You may have a full course load, have a part-time job, compete in athletics, or need to care for your family. Therefore, the schedule that works best will vary from one student to another, but my advice is set a specific schedule.

There is a rhythm to the course; assignments are very regular. The rhythm is meant to help keep you engaged and on pace.

Students with Accessibility Needs

Rose-Hulman is committed to working with students who have special needs or disabilities. Such students may be eligible to receive accommodations that provide equal access to learning, the living and learning environment, and college activities. Visit the **Accessibility Services website** for more information. Requests for academic accommodations must be documented with and approved by the Accessibility Services office before they can be implemented in this course.

Emergency Information

To receive email or text messages regarding emergency situations that may impact campus and, possibly, the delivery of classes, register for RAVE alerts and/or follow @Rose-HulmanAlert on Twitter. Any announcements about the Institute's ability to offer classes will be shared on Rose-Hulman's website.

Student Handbook

This course adheres to all policies described in the **Student Handbook**. A few key sections are briefly outlined below. In brief, Rose-Hulman expects its students to be responsible adults and to behave at all times with honor and integrity. All students are expected to abide by this code and to aid in its enforcement by reporting violations of it.<\p>

Dropping the Course

You are responsible for understanding the university's policies and procedures regarding withdrawing from courses found in the current catalog. You should be aware of the current deadlines according to the **Rose-Hulman Academic Calendar.** More information for Drops and Adds can be found on the **Registrar's site here**.

Academic Integrity

Academic integrity is an integral part of the Rose-Hulman community. It is important that all members of our community learn to properly acknowledge the important contributions of others in our respective fields, both within Rose-Hulman and external to Rose-Hulman. Understanding how to work in collaboration with others and how to incorporate their work into your own, and then appropriately acknowledging them, demonstrates your intellectual maturity and a high degree of professionalism. Academic integrity refers to maintaining a high standard of honesty in academic conduct. All students and faculty are encouraged and required to show academic integrity at all times. On the other hand, academic misconduct is a failure of academic integrity. Specifically, academic misconduct is cheating, plagiarism, or interfering with the academic progress of other students.

The **Academic Rules and Procedures document** provides extensive rules and procedures for academic and other misconduct. The Mathematics Department **follows these rules seriously**. The minimum penalty for such misconduct is for the instructor to award zero credit for whatever test, exam, project or quiz on which the misconduct occurs, even if it results in a lowered or failing grade. A report of the misconduct will be sent to the Dean of Students and the Mathematics Department Head. Faculty members may exact a higher penalty, up to and including failure in the course if they feel the misconduct warrants such action. Students may appeal the sanctions to the rules and discipline committee, per the cited web page.

Plagiarism is a serious offense, and students are expected to adhere to the Rose-Hulman policy on plagiarism and cheating. Some individuals might say that they did not understand what plagiarism was when they took credit for someone else's ideas, but ignorance is not an excuse for lack of academic integrity. It is each student's responsibility to know the Rose-Hulman policy on academic honesty, including plagiarism, cheating, dishonest conduct, and collusion. This not only includes misrepresenting others' work as your own, but also summarizing, paraphrasing, use of any other material in your work, and incorrect or incomplete citations and references. Using the same work for multiple courses is also dishonest. If you have any questions concerning rules, procedures, or about academic honesty, plagiarism, cheating, dishonest conduct or collusion, please speak with your instructor.

Course Information Copyrights

Diversity Statement

Rose-Hulman is commited to being an **inclusive community** in which the multiplicty of values, beliefs, intellectual viewpoints, and cultural perspectives enrich learning and inform scholarship.

Online Access Requirements

Rose-Hulman welcomes students from around the world and encourages faculty, staff, and students to travel around the world. However, geopolitical conditions and compliance with export law and regulations prevent us from delivering certain kinds of educational experiences and/or using certain kinds of Institute technologies in some locations. For example, students in locations with limited access to the internet in general, or with restricted access to portions of the internet, or which are embargoed by the U.S. Directorate of Defense Trade, may not be able to successfully complete Rose-Hulman courses.

Disclaimer

The instructor reserves the right to modify the course content, schedule, topics, policies, etc. outlined in this syllabus.