MATH 7393 001 – Bayesian Statistics
Department of Mathematical and Statistical Sciences
College of Liberal Arts and Sciences
University of Colorado Denver
Spring 2025

Instructor: Joshua French
Office: SCB 4213
Email: joshua.french@ucdenver.edu
Course website: https://ucdenver.instructure.com
Twitter: @J0shua_French (has a focus on statistics and R related tips).
YouTube: https://youtube.com/@jfrench (some Bayesian content)
Code:

Class Meeting Times: Tuesday and Thursday from 12:30-1:45p in SCB-4017.

In the event that I must meet remotely, then in-class times can be accessed via the course-specific zoom link:
https://ucdenver.zoom.us/j/99344670129?pwd=Nsj1xPPFakY4vIjyni9L7OY8poaIuP.1.

Office Hours: Tuesday and Thursday from 2-3p and by appointment.

Course Description: Prior and posterior distributions, conjugate models, single and multiparameter models, hierarchical models, numerical methods for evaluating posteriors, Monte Carlo methods, and Markov chain Monte Carlo.

Overview: The Bayesian approach to statistical inference and data analysis has exploded in popularity since the 1980s. This course will teach you the fundamentals of Bayesian statistical inference and how to perform Bayesian analysis on real data. You will also learn how to use statistical software to perform Bayesian analysis and construct standard applied models.

Prerequisite: Math 4387/5387 Applied Regression Analysis.

Required Textbooks: None. Most students find the lecture notes sufficiently descriptive.

Optional Textbooks:

Bayesian Data Analysis, 3rd edition by Gelman, Carlin, Stern, Dunson, Vehtari, and Rubin. ISBN: 978-1439840955. We'll refer to this book as BDA3. BDA3 is the gold standard textbook for Bayesian statistics, but not as hands-on as BMUW. The book is available in pdf form from the author here: http://www.stat.columbia.edu/~gelman/book/

- *Bayesian Modeling Using WinBUGS* by Ioannis Ntzoufras. ISBN: 978-0470141144. We'll refer to this book as BMUW.
- *A First Course in Bayesian Statistical Methods* by Peter Hoff. ISBN: 978-0-387-92407-6. This is a solid introduction to Bayesian statistical methods.
- *Doing Bayesian Data Analysis*, 2nd edition by John Kruschke. ISBN: 978-0124058880. This is an introductory level book on Bayesian analysis, but the book is very practical and includes numerous coding examples.
- *Statistical Rethinking: A Bayesian Course with Examples in R and Stan* by Richard McElreath. ISBN: 978-1482253443. This is another introductory level book on Bayesian data analysis. The author provides many coding examples and provides video lectures.
- *Bayes Rules!* An Introduction to Applied Bayesian Modeling by Alicia A. Johnson, Miles Q. Ott, Mine Dogucu. https://www.bayesrulesbook.com/.

Computing: We will use several free software systems for performing Bayesian data analysis in this class. These include:
- R - a free, cross-platform statistical software package that is extremely powerful. It is the standard statistical computing language in academia and is becoming more popular in the public and private sector. https://www.r-project.org.
- RStudio - a free and open source integrated development environment (IDE) for R available at https://www.rstudio.com/. RStudio is also cross-platform and has many nice features (like the ability to scroll through your plots, syntax highlighting, viewing the objects in your environment, etc.) that you may find useful.
- Stan - A probabilistic modeling language used as a platform for Bayesian inference. It is modern, fast, open-source, and can be called directly from R. The official website is https://mc-stan.org/, though we will use the software through the **rstan** package.

Couse Goals and Outcomes:

Overall Learning Objectives

By the end of this course, students should be able to:
- Solve probability questions important in statistics using Bayesian inference.
- Formulate statistical problems from a verbal or written description.
- Construct sensible statistical models from the context and description of a problem
- Interpret statistical results in complete and understandable English sentences.
- Perform statistical analysis with the aid of statistical software

Learning Outcomes

Several specific learning outcomes will be strengthened in this course. Among them are:
- Critical Thinking
- Inquiry and Analysis
- Quantitative Literacy

Critical thinking will be necessary to some degree in every course assignment. When performing statistical inference, one will have to weigh the evidence before drawing a conclusion.

Inquiry and Analysis will be important in every homework assignment, as well as the exams and project. Statistics involves considering a hypothesis or question of interest and analyzing data to determine the answer.

Quantitative Literacy will be promoted in all homework assignments, exams, and the project. Each of these assignments will require you to work with data and numbers to answer questions and convincingly argue for certain conclusions. This will be most evident in the final project.

Major Topics

This course will cover the most important concepts and concepts of Bayesian statistical inference and data analysis. We will learn the substantive differences between Bayesian and frequentist approaches to statistics. We will discuss common one-parameter and multiparameter statistical models and how to evaluate the fit of a Bayesian statistical model. We will learn computational methods for performing Bayesian statistical analysis, particularly Markov chain Monte Carlo (MCMC) methods. We will cover numerous standard Bayesian models for common types of data.

Rationale

Bayesian statistics is becoming an increasingly popular approach to statistics. Its usage was initially limited to a small group of statisticians (and problems), but it is now an extremely popular approach to statistical analysis. A modern data scientist needs to be conversant in Bayesian statistical analysis. Bayesian analysis involves many important computational tools, so discussion and creation of computational statistical methods is an important component of the course. Your programming and computational ability should improve immensely in this course, which will help prepare you for statistical positions you may take upon graduation.

Grades:

Assignments

Homework: Homework problems will be assigned for each section of material. On the designated days, students are expected to submit a pdf version of their homework through Canvas by the assigned deadline. Some of the assigned problems will be selected for grading (as few as one problem and as many as all of them). These problems alone will be used to determine a student's grade for that assignment. Assignments must be typed in an appropriate word processor (like Microsoft Word or Libre Office) or typeset using an appropriate program (like LaTeX) and should use appropriate mathematical notation. Individual problems should be clearly numbered and problem parts should be clearly

labeled. Relevant computer code and output should be provided with your answer to each problem (for snippets of code) or as an appendix (for lengthy amounts of code). The font used for computer code should be fixed-width (e.g., `Courier New`, `Monaco`, or `Consolas`) to preserve formatting. Your short answers should use a different font from your computer code, e.g., Times New Roman, Cambria, or Arial to distinguish your answer from the computer code.

Exams*:* There will be two exams during the semester. **The first exam will be on Thursday, March 13th. The second exam will be a take-home exam due on May 1st.** Without prior approval or a documented health, disability, or emergency reason, missed exams will be scored as a zero.

Project*:* All students will be expected to complete a final project demonstrating their mastery of the material in this course. This will include both an oral presentation and a written report. The project presentations are tentatively scheduled to be presented on **Thursday, May 8th**. The report will be due **by the final exam time (TBD)**.

Grade determination

Final grades will be determined by the following weighting scheme:

Homework   1/3
Exams   1/3
Project   1/3

Letter grades will be based on the following scale:

Percentage	**Letter Grade**
92 or higher	A
90 up to 92	A-
88 up to 90	B+
82 up to 88	B
80 up to 82	B-
78 up to 80	C+
70 up to 78	C
68 up to 70	D+
62 up to 68	D
60 up to 62	D-
Below 60	F

I reserve the right to lower or raise this scale as needed. This is generally only necessary to ensure borderline grades are appropriately assigned a letter grade, although it may be necessary to adjust for overly difficult or overly easy exams.

Grade/Assignment Dissemination

Grades will be provided via the course's Canvas course shell. You can access your scores at any time within the Canvas gradebook. Assignments will be returned electronically.

Expected effort and tips for success:
- This class requires certain prerequisite knowledge (especially about probability and statistical distributions. This knowledge is essential for success in this class.
- This is a graduate level course. Expect to work hard. Expect to work between 6 to 10 hours per homework assignment. Expect to study for exams. Simply attending lectures will not prepare you for success in this course. You will need to work hard to apply the concepts and tools we discuss during class time.
- Class attendance and participation is expected.
- Students are expected to ask questions (during class or office hours) if they are confused. It is your responsibility to ask for help!
- Students are expected to read the relevant sections of the book. The book provides additional details that I will not cover in class. Material should be read BEFORE the appropriate lectures.
- Homework should be completed as the homework sets are assigned. Students will find little benefit in rushing to complete homework assignments.

Class pedagogy:
- There will typically be some aspect of lecturing during our usual course times.
- I sometimes use video lectures to supplement in-class learning and may even use them to facilitate in-depth classroom activities and data analysis.
- Course announcements will be made frequently through Canvas and/or email. You are responsible for the information contained in any announcements or messages I send you, regardless of whether the information is repeated in class. It is your responsibility to frequently check Canvas and to maintain your university email address.

Classroom policies:
- Students are expected to enter class **on time** and remain in class for the duration of the class period.
- Students should not eat during class time.
- Students are expected to behave in a professional manner during class time.
- Discussion and questions are highly encouraged!
- Cell phones and other electronic devices should be silenced during class.
- Computers should not be used during class time unless it is directly related to the course (note taking, executing computer code, etc.)

Tentative Course Schedule: The following course schedule is tentative. The exam due dates are fixed but the material covered on the exams is subject to change. Homework assignment due dates will be determined by how quickly we move through material and will be given throughout the semester. I reserve the right to modify this schedule as the semester progresses.

Date	Day	Week	Agenda Topic	Reading	Due
21-Jan	T	1	Bayesian Inference	Ch 1-2.3 - BDA	
23-Jan	R	1	Bayesian Inference	Ch 1-2.3 - BDA	
28-Jan	T	2	Single-parameter models	Ch 2.4-2.9 - BDA	
30-Jan	R	2	Single-parameter models	Ch 2.4-2.9 - BDA	Hw 1
4-Feb	T	3	Single-parameter models	Ch 2.4-2.9 - BDA	
6-Feb	R	3	Single-parameter models	Ch 2.4-2.9 - BDA	Hw 2
11-Feb	T	4	Computational Methods	Ch 10 - BDA	
13-Feb	R	4	Computational Methods	Ch 10 - BDA	Hw 3
18-Feb	T	5	Computational Methods	Ch 11 - BDA	
20-Feb	R	5	Computational Methods	Ch 11 - BDA	Hw 4
25-Feb	T	6	Computational Methods	Ch 11 - BDA	
27-Feb	R	6	Computational Methods	Ch 11 - BDA	Hw 5
4-Mar	T	7	Introduction to Stan		
6-Mar	R	7	Introduction to Stan		
11-Mar	T	8	Normal Error Models	Ch 5 - BMUW	Hw 6
13-Mar	R	8	Exam 1		
18-Mar	T	9	Normal Error Models	Ch 5 - BMUW	
20-Mar	R	9	Normal w/ Categorical	Ch 6 - BMUW	Hw 7
25-Mar	T		Spring Break		
27-Mar	R		Spring Break		
1-Apr	T	10	Normal w/ Categorical	Ch 6 - BMUW	
3-Apr	R	10	GLMs (Poisson)	Ch 7 - BMUW	Hw 8
8-Apr	T	11	GLMs (Poisson)	Ch 7 - BMUW	
10-Apr	R	11	GLMs (Binomial)	Ch 7 - BMUW	Hw 9
15-Apr	T	12	GLMs (Binomial)	Ch 7 - BMUW	
17-Apr	R	12	GLMs (Negative Binomial)	Ch 8 - BMUW	Hw 10
22-Apr	T	13	Model Checking	Ch 6 - BDA3	
24-Apr	R	13	Model Checking	Ch 6 - BDA3	Hw 11
29-Apr	T	14	Hierarchical Models	Ch 9 - BWUW	
1-May	R	14	Exam 2		
6-May	T	15	Hierarchical Models	Ch 9 - BWUW	
8-May	R	15	Final Presentation		
May 12-16			Finals Week		

I reserve the right to modify this syllabus as the semester progresses.

University, college, and department policies

Academic Calendar
For university deadlines and procedures (such as the last day to withdraw from a course), please see the Academic Calendar. https://www.ucdenver.edu/student/calendars/academic/

Academic Support
Instructor office hours or other appointments are the best way to get additional help. I'm happy to help with questions not answered during class, additional explanation, or homework assistance.
Other sources of support are
- The Math and Stat Support office is located in the Learning Commons Building Room 1225 and regularly offers CU Denver students free drop-in assistance. Hours of operation, zoom links for virtual options, and other forms of support for mathematics and statistics courses are available on the Math and Stat Support webpage. https://clas.ucdenver.edu/mathematical-and-statistical-sciences/math-and-stat-support
- The Learning Resources Center (LRC) provides individual and group tutoring, Supplemental Instruction (SI), study skills workshops, and ESL support.
https://www.ucdenver.edu/learning-resources-center
- The College of Liberal Arts and Sciences has a summary of campus academic support and school/college advising offices. https://clas.ucdenver.edu/faculty-staff/content/clas-academic-policies-deadlines

Recording of Class Meetings
Class meetings held on or streamed over a video conferencing platform (such as Zoom, Microsoft Teams, etc) may be recorded and posted for all members of the class. Student participation and interaction may be included in the recording. If you have any concerns about this, please contact the instructor.

Diversity Statement
It is my intent that students from all diverse backgrounds and perspectives be well served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength and benefit. It is my intent to present materials and activities that are respectful of diversity: gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture, etc. I would like to create a learning environment for my students that supports a diversity of thoughts, perspectives and experiences, and honors your identities (including race, gender, class, sexuality, religion, ability, etc). To help accomplish this:
- If you have a name and/or set of pronouns that differ from those that appear in your official records, please let me know!
- If you feel like your performance in the class is being impacted by your experiences outside of class, please don't hesitate to come and talk with me. I want to be a resource for you. Remember that you can also submit anonymous feedback (which will lead to me making a general announcement to the class, if necessary to address your concerns). If

you prefer to speak with someone outside of the course, the Office of Diversity, Equity and Inclusion, is an excellent resource.

- I (like many people) am still in the process of learning about diverse perspectives and identities. If something was said in class (by anyone) that made you feel uncomfortable, including by me, please talk to me about it. (Again, anonymous feedback is always an option).

Your suggestions are encouraged and appreciated. Please let me know ways to improve the effectiveness of the course for you personally or for other students or student groups. In addition, if any of our class meetings conflict with your religious or other cultural events, please let me know so that we can make arrangements for you.

Health and Wellness

As a student, you may experience a range of challenges that can interfere with learning, such as strained relationships, traumas, increased anxiety, substance use, feeling down, difficulty concentrating, and/or lack of motivation. These mental health concerns or stressful events may diminish your academic performance and/or reduce your ability to participate in daily activities. If you or someone you know is struggling, you can find supportive campus and community resources at the Health Center at Auraria or the CU Denver Counseling Center. On weekends, holidays or after-hours you can contact the 24/7 Mental Health Crisis and Victim Assistance Line at 303-615-9911.

The University of Colorado Denver is committed the health and well-being of all students. We recognize that diminished mental health, including significant stress, mood changes, excessive worry, or problems with eating and/or sleeping can interfere with optimal academic performance. The source of such symptoms can be quite varied, and include experiences of trauma (such as sexual and relationship violence, stalking, discrimination, crimes, and accidents), responses to course work, family worries, loss, personal struggle, or crisis. If you or someone you know is struggling, you can find supportive campus and community resources at https://www.ucdenver.edu/counseling-center

or by calling the CU Denver Counseling Center (303-315-7270) or the Health Center at Auraria (303-615-9999). On weekends, holidays or after-hours you can contact the 24/7 Mental Health Crisis and Victim Assistance Line at 303-615-9911.

Disability Accommodation and Access

The University of Colorado Denver is committed to ensuring the full participation of all students in its programs, including students with disabilities. If you have a disability or think you have a disability and need accommodations to succeed in this course, I encourage you to contact Disability Resources and Services (DRS) and/or speak with me as soon as you can. DRS is located in Student Commons Building Suite 2116, and can be reached at disabilityresources@ucdenver.edu and online at https://www.ucdenver.edu/offices/disability-resources-and-services. I am committed to providing equal access as required by federal law, and I am interested in developing strategies for your success in this course.

Nondiscrimination and Sexual Misconduct

The University of Colorado Denver is committed to maintaining a positive learning, working and living environment. University policy and Title IX prohibit discrimination on the basis of race, color, national origin, sex, age, disability, pregnancy, creed, religion, sexual orientation, veteran status, gender identity, gender expression, political philosophy or political affiliation in

admission and access to, and treatment and employment in, its educational programs and activities. University policy prohibits sexual misconduct, including harassment, domestic and dating violence, sexual assault, stalking, or related retaliation. If you have experienced any sort of sexual misconduct or discrimination, please visit the Office of Equity web site at https://www.ucdenver.edu/offices/equity to understand the resources available to you or contact the Office of Equity/Title IX Coordinator at equity@ucdenver.edu.

Please note that I am a Responsible Employee, which means that if I witness or receive information regarding possible prohibited protected characteristic discrimination or harassment, any form of sexual misconduct, and/or related retaliation, I am required to promptly report the information to the Office of Equity or their designee.

Religious Holiday Accommodation

Faculty in the University of Colorado system provide reasonable accommodations to students who must be absent from classes because of religious holidays. If you will miss class or graded assignments in order to observe religious holidays, you must contact me with all course conflicts by the end of the first week of classes.

Student Code of Conduct

As members of the University community, students are expected to uphold university standards, which include abiding by state civil and criminal laws and all University policies and standards of conduct. These standards are outlined in the student code of conduct, which can be found at https://www.ucdenver.edu/student/wellness/student-conduct

Academic Honesty

Students are expected to know, understand, and comply with the ethical standards of the university. A university's reputation is built on a standing tradition of excellence and scholastic integrity. As members of the University of Colorado Denver academic community, faculty and students accept the responsibility to maintain the highest standards of intellectual honesty and ethical conduct.

Academic dishonesty is defined as a student's use of unauthorized assistance with intent to deceive an instructor or other such person who may be assigned to evaluate the student's work in meeting course and degree requirements.

This course assumes your knowledge of the policies and definitions. University policies allow the instructor to decide how to respond to an ethics violation, whether by lowering the assignment grade, lowering the course grade, and/or filing charges against the student with the campus Office of Student Conduct. For more information regarding the Office of Student Conduct policies and procedures, please refer to https://www.ucdenver.edu/student/wellness/student-conduct/academic-integrity. Violating the academic honor code can lead to expulsion from the University.

Examples of academic dishonesty include, but are not limited to, the following:

Plagiarism.

Plagiarism is the use of another person's distinctive words or ideas without acknowledgment. Examples include:
1. Word-for-word copying of another person's ideas or words;

2. The mosaic (the interspersing of one's own words here and there while, in essence, copying another's work);
3. The paraphrase (the rewriting of another's work, yet still using their fundamental idea or theory);
4. Fabrication of references (inventing or counterfeiting sources);
5. Submission of another's work as one's own;
6. Neglecting quotation marks on material that is otherwise acknowledged.

Acknowledgment is not necessary when the material used is common knowledge.

Cheating.
Cheating involves the possession, communication, or use of information, materials, notes, study aids or other devices not authorized by the instructor in an academic exercise, or communication with another person during such an exercise. Examples include:
1. Copying from another's paper or receiving unauthorized assistance from another during an academic exercise or in the submission of academic material;
2. Using a calculator when its use has been disallowed;
3. Collaborating with another student or students during an academic exercise without the consent of the instructor.

Note on use of Generative AI.
Generative AI tools such as ChatGPT may not be used on exams, tests, or quizzes that do not permit the use of outside resources. The instructor will provide guidelines on whether such tools can be used for assignments and projects.

Fabrication and Falsification.
Fabrication involves inventing or counterfeiting information, i.e., creating results not obtained in a study or laboratory experiment. Falsification, on the other hand, involves the deliberate alteration of results to suit one's needs in an experiment or other academic exercise.

Multiple Submissions.
This is the submission of academic work for which academic credit has already been earned, when such submission is made without instructor authorization.

Misuse of Academic Materials.
The misuse of academic materials includes, but is not limited to, the following:
1. Stealing or destroying library or reference materials or computer programs;
2. Stealing or destroying another student's notes or materials, or having such materials in one's possession without the owner's permission;
3. Receiving assistance in locating or using sources of information in an assignment when such assistance has been forbidden by the instructor;
4. Illegitimate possession, disposition, or use of examinations or answer keys to examinations;
5. Unauthorized alteration, forgery, or falsification;
6. Unauthorized sale or purchase of examinations, papers, or assignments.

Complicity in Academic Dishonesty.
Complicity involves knowingly contributing to another's acts of academic dishonesty. Examples include:

1. Knowingly aiding another in any act of academic dishonesty;
2. Allowing another to copy from one's paper for an assignment or exam;
3. Distributing test questions or information about the materials to be tested before the scheduled exercise;
4. Taking an exam or test for someone else;
5. Signing another's name on attendance roster or on an academic exercise.

Incomplete Policy
When a student has special circumstances that make it impossible to complete course assignments, faculty members may choose to award an incomplete grade. All incomplete courses are assigned a grade of Incomplete (I). Incomplete grades are not awarded for poor academic performance or as a way of extending assignment deadlines. Faculty are not required to award an Incomplete.
To be eligible for an Incomplete grade, students MUST:
- Have participated in the class for a significant proportion of the term.
- Have successfully completed a significant proportion of the course assignments.
- Have special circumstances (verification may be required) that preclude the student from attending class and/or completing graded assignments.
- Make arrangements to complete missing assignments with the original instructor by a mutually agreed upon date but within one calendar year. Note that it is not the instructor's responsibility to teach the student missed material.
- Both the instructor and student should complete and sign a Course Completion Agreement found at
https://clas.ucdenver.edu/faculty-staff/content/incomplete-grade-policy
- The instructor gives a copy of the signed Course Completion Agreement to the department.

Incompletes cannot:
- require a student to repeat the entire course,
- repeat or replace existing grades,
- allow the student an indeterminate period of time to complete a course, or
- allow the student to repeat the course with a different instructor.

Student Grievances
Students who have concerns about the course or instructor should first contact the instructor to discuss the issue. If the issue is not resolved, the student should next contact the Associate Chair of the Department of Mathematical and Statistical Sciences (currently Stephen Hartke <stephen.hartke@ucdenver.edu>). If not satisfied, the student should then appeal to the appropriate Associate Dean of the student's home school or college (for CLAS, this is the Associate Dean for Student Success). No step in this process should be skipped.