Syllabus

Introduction to Mathematical Modeling

MATH 331, Section 001

Basic Course Information

Course Name: Introduction to Mathematical Modeling

Semester: Fall, 2025

Credits: 3

Prerequisites/Co-requisites:
MATH 161 (Calculus for Physical Scientists II)
DSCI 369 (Linear Algebra for Data Science) or MATH 369 (Linear Algebra I)
may be taken concurrently

Meetings/Times: Monday, Wednesday, Friday, 2:00 to 2:50 PM

Location: Weber 202

Instructor Information

Instructor Name: Steve Benoit

Email: steve.benoit@colostate.edu (mailto:steve.benoit@colostate.edu)

Office Location: Weber 112

Office Hours/Student Hours: Tuesdays 2:00 - 3:00, and Fridays 12:00 - 1:00, both in Weber 112.

Communication Policy: The best way to reach me is via email. I will respond to class-related emails within 24 hours on weekdays, or by Monday for emails sent over a weekend.

Course Materials

Textbook / Course Readings

There is no required textbook.

All necessary materials will be provided in class and shared on Canvas.

Course Description & Objectives

Catalog Description: Problem formulation. Modeling, theoretical and empirical. Variable selection. Derivation and simulation of solutions. Model testing including prediction.

More Detailed Description: This course examines several types of mathematical modeling spanning many contexts and situations. It explores graphical and tabular models, discrete models, geometric models, regression and experimental models and simulations, and spatial models. It wraps up with a discussion of optimization.

Course Learning Objectives: Upon completion of this course, students will be able to:

A. Describe the role of numbers, functions, graphs, diagrams, tables, algorithms, and relations (equations, inequalities) in modeling phenomena.
B. Recognize a wide variety of situations and contexts as opportunities for mathematical modeling.
C. Develop multiple approaches to modeling a situation or scenario using various mathematical tools.
D. Implement models using various methods and justify choices made in their construction.
E. Apply models to make predictions or describe the behavior of the system under study.
F. Evaluate the validity of models and identify assumptions and limitations of a model.

Assignments

Daily Individual and Group Activities:

There will be daily activities in class that develop understanding of modeling techniques. These are due at the end of class each day. Some of these will be completed individually, and some will be completed in groups, with one submission per group.

These activities are graded on completion and effort; there is often no single correct answer.

Weekly Homework:

At the end of each week there will be a homework assignment to practice some of the techniques learned during that week. These homework sets are to be completed individually and will be due on Wednesdays (starting week 2).

Homework sets may include some analytical questions that involve computation, and some reflective questions with written responses. They will be graded out of some number of points, where the scores on reflective questions are based on how “substantive” the response was and how well it addressed the prompt.

Group Projects:

The course includes three group projects that involve designing and constructing a model of some situation, reflecting on the accuracy and applicability of the model, and using the model to make predictions. Groups will turn in a write-up of their model and will share their design with the class (informally, not as a formal presentation). Groups will spend at least a week on each project. The grading of the projects will be based on how well they demonstrate the course learning objectives.

Course Schedule

Course Schedule

Date	Mod	Topic	Objectives	Assignments
Aug. 25 (M)	0.1	Introduction to modeling	A	Act 0.1
Aug. 27 (W)	1.1	The modeling process	B, C	Act 1.1
Aug. 29 (F)	1.2	Problem characterization	B, C	Act 1.2
Sep. 1 (M)		**LABOR DAY HOLIDAY**		
Sep. 3 (W)	1.3	Formulation; stochastic processes	B, C, D	Act 1.3
Sep. 5 (F)	2.1	Dimensional Analysis	A, C, F	Act 2.1, Homework 1 (**due Sep. 10**)
Sep. 8 (M)	2.2	Scaling	A, B	Act 2.2
Sep. 10 (W)	2.3	Approximation and Reasonableness	D, E, F	Act 2.3
Sep. 12 (F)	3.1	Introduction to game theory	A, B	Act 3.1, Homework 2 (**due Sep. 17**)
Sep. 15 (M)	3.2	Two-player simultaneous games	A, B	Act 3.2
Sep. 17 (W)	3.3	Cooperative games	A, B	Act 3.3
Sep. 19 (F)	3.4	Creating a model of a game	C, D, E, F	Act 3.4, Homework 3 (**due Sep. 24**)
Sep. 22 (M)	4.1	Modeling with difference equations	B, C, D, E	Act 4.1
Sep. 24 (W)	4.2	Systems of difference equations	D	Act 4.2
Sep. 26 (F)	4.3	Multiple equilibria, tipping points	B, E, F	Act 4.3, Homework 4 (**due Oct. 1**)
Sep. 29 (M)		PROJECT 1: SELECTION		Act Proj. 1.1, Project 1 (**due Oct. 10**)
Oct. 1 (W)		PROJECT 1: MODEL DESIGN		Act Proj. 1.2
Oct. 3 (F)		PROJECT 1: MODEL DESIGN		Act Proj. 1.3
Oct. 6 (M)		PROJECT 1: SHARE AND DISCUSS		Act Proj. 1.4
Oct. 8 (W)		PROJECT 1: SHARE AND DISCUSS		Act Proj. 1.5
Oct. 10 (F)	5.1	Experimental modeling (case study)	A, C, D, E, F	Act 5.1 **(remote class - football game)**
Oct. 13 (M)	5.2	Sampling, Surveys, and Bias	B, C, F	Act 5.2
Oct. 15 (W)	5.3	Fitting data graphically, uncertainty	A, D, E, F	Act 5.3
Oct. 17 (F)	5.4	Analytic curve fitting, least squares	D, F	Act 5.4, Homework 5 (**due Oct. 22**)
Oct. 20 (M)	5.5	Piecewise and Spline models	A, B, C, D, E, F	Act 5.5
Oct. 22 (W)		PROJECT 2: SELECTION		Act Proj. 2.1, Project 2 (**due Nov. 3**)
Oct. 24 (F)		PROJECT 2: MODEL DESIGN		Act Proj. 2.2, Homework 6 (**due Oct. 29**)
Oct. 27 (M)		PROJECT 2: MODEL DESIGN		Act Proj. 2.3
Oct. 29 (W)		PROJECT 2: SHARE AND DISCUSS		Act Proj. 2.4
Oct. 31 (F)		PROJECT 2: SHARE AND DISCUSS		Act Proj. 2.5
Nov. 3 (M)	6.1	Simulation, Deterministic Systems	A, B, C	Act 6.1
Nov. 5 (W)	6.2	Monte Carlo methods	A, B, C	Act 6.2
Nov. 7 (F)	6.3	Probabilistic models	C, D, E, F	Act 6.3, Homework 7 (**due Nov. 12**)
Nov. 10 (M)	6.4	Queueing models	C, D, E, F	Act 6.4
Nov. 12 (W)	7.1	Optimization, linear programming	D, E, F	Act 7.1
Nov. 14 (F)	7.2	Optimization, simplex method	D, E, F	Act 7.2, Homework 8 (**due Nov. 19**)
Nov. 17 (M)		PROJECT 3: SELECTION		Act Proj. 3.1, Project 3 (**due Dec. 3**)
Nov. 19 (W)		PROJECT 3: MODEL DESIGN		Act Proj. 3.2
Nov. 21 (F)		PROJECT 3: MODEL DESIGN		Act Proj. 3.3
Nov. 24 – 28		**FALL BREAK**		
Dec. 1 (M)		PROJECT 3: SHARE AND DISCUSS		Act Proj. 3.4
Dec. 3 (W)		PROJECT 3: SHARE AND DISCUSS		Act Proj. 3.5, Posters (**due Dec. 11**)
Dec. 5 (F)	8.1	Spatial models – GIS	A, B, C, D	Act 8.1, **Posters ready to print**
Dec. 8 (M)	8.2	Spatial models – VR	B, C, D	Act 8.2, Homework 9 (**due Dec. 12)**
Dec. 10 (W)	8.3	Spatial data models, visualization	B, D, F	Act 8.3
Dec. 11 (Th)		Poster Session in LSC		
Dec. 12 (F)		Course wrap-up		Course Survey

Morgan Library Services Desk

The Morgan Library Services Desk provides both research (ph. 970-491-1841) and technical (ph. 970-491-7276) support. In addition, you can contact a librarian for assistance at **Ask Us!** (https://lib.colostate.edu/services/ask-us/) or find a research guide at **Research Help** (https://libguides.colostate.edu/) .

Classroom Norms

A welcoming classroom is a place where ideas can be shared freely and comfortably, and where everyone feels that they can contribute without fear. The values expressed in the CSU Principles of Community are a strong foundation for creating such a space, but it requires a commitment on the part of both the students in the course and the instructor to uphold these values each day.

In particular,

- We will listen to each other with the intent to understand different perspectives. This is a class where there are often many valid answers or approaches, and we all grow by hearing many perspectives.
- We will ask questions when we have them and create a space that invites questions and discussion.
- We will work to make sure everyone's voice is heard.
- In discussions, we will strive to communicate both honestly and respectfully.

CSU Principles of Community

Inclusion: We create and nurture inclusive environments and welcome, value and affirm all members of our community, including their various identities, skills, ideas, talents and contributions.

Integrity: We are accountable for our actions and will act ethically and honestly in all our interactions.

Respect: We honor the inherent dignity of all people within an environment where we are committed to freedom of expression, critical discourse, and the advancement of knowledge.

Service: We are responsible, individually and collectively, to give of our time, talents, and resources to promote the well-being of each other and the development of our local, regional, and global communities.

Social Justice: We have the right to be treated and the responsibility to treat others with fairness and equity, the duty to challenge prejudice, and to uphold the laws, policies and procedures that promote justice in all respects.

Diversity and Inclusion

Everyone in our classroom has had a unique life journey that has led them to this place and has a unique set of experiences and strengths.

It is my intent that every student, each with their own background, interests, 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. 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 events, please let me know so that we can make arrangements for you.

Course Policies

Your regular attendance and participation in the class is expected.

For “individual assignments”, you are welcome to talk to others and discuss how to approach any assignment, but the work you turn in should be your own (not a copy of another student's work, and not the output of an A.I.).

For “group assignments”, including class projects, members of a group should collaborate and strive to produce a work product that they are all happy with. All group members will earn the same grade, unless some extraordinary circumstance makes it clear that this is not equitable, in which case that situation will be assessed on a case-by-case basis. Students are free to use resources like search engines and A.I. tools to formulate their thoughts and ideas, but the synthesis of these ideas into a final output must come from the group members, not outside resources.

Daily activity / engagement assignments are designed to keep students engaged and actively learning. There are roughly 43 of these assignments. I understand that circumstances will sometimes require you to miss a class or two, so only **40 of these will be counted** toward your grade (you can miss 3 without penalty). These count **3 points each**, for **120** total points. Some will be individual assignments, some will be done in pairs, some will be done in larger groups.

These are graded according to the following rubric:

- Attempted the activity but little effort is evident = 1 point
- Demonstrated effort to complete all parts of the activity = 2 points
- All parts completed according to instructions = 3 points

Homework assignments are designed to give you individual practice with the skills described in the course. They should be done individually. There are **9 of these** assignments. These count **20 points each**, for **180** total points. Homework can be turned in late without a penalty for excused absences, or late with a 2-points-per-weekday penalty otherwise, up to 9 weekdays late (with the exception that all homework must be turned in by the last day of classes to earn credit).

The rubric for homework may vary from assignment to assignment, but will generally assign some number of points to each question assigned, with scores being determined on some scale that resembles the following:

- Tried beyond just rewriting or paraphrasing the question – ¼ of points
- Used a reasonable approach and made progress, but did not finish, or finished with significant errors – ½ of points
- Finished with few errors – ¾ of points
- Finished with no errors, or trivial errors – full points

Group projects are designed to practice the high-level learning objectives for the course. They include not only creating a model but considering and documenting alternative approaches that could have been used, evaluating the model with respect to its expected accuracy or usefulness, and describing any limitations the model has or assumptions on which it is based.

Groups will work on projects both in class and outside of class. The assignments should provide flexible approaches to participating, and all groups should develop plans that enable all members to contribute equitably. If your group encounters challenges in doing so, please reach out to me so we can work together to devise a solution.

Models will be written up using a supplied template and turned in (one submission for each group). All group members will receive the same score (see notes above). There are **3** group assignments, each worth **100 points** for a total of **300 points**. Each group assignment will be graded using the following rubric (these categories are clearly indicated in the template).

- Documented at least 2 different (but reasonable) approaches to the problem, or if only one approach was considered, why it was the only reasonable approach (**25 pts**)
- Documented the model itself, in a format that is appropriate to the model (**25 pts**)
- Documented how or why the model's behavior is a good match to the system being modeled, and how one would use the model to make predictions or understand the system (**25 pts**)
- Documented any assumptions on which the model is based (along with some description of how likely it might be that these are not met), and described any limitations of the model in terms of its ability to reliably mimic the real-world system it is modeling. This can include descriptions of factors that the model does not consider but that could significantly change system behavior (**25 pts**).

Life sometimes throws us unexpected challenges. If you find you are struggling to keep up with the course, please contact me. I'm here to help!

Grading Policy

The assignments in the course count toward total grade as follows:

There are no exams in this course.

Course Assignment Weights

ASSIGNMENT	GRADE POINTS	GRADE PERCENTAGE
Daily Activities (40 counted out of 44 planned, 3 points each)	120	20 %
Weekly homework assignments (9, 20 points each)	180	30 %
Group Projects (3, 100 points each)	300	50 %
Total:	**600**	**100 %**

Grades will be assigned according to the table below. You may notice that there is no A– row in the table. Since the “minus” on an A grade affects GPA (it counts as 3.67), but “plus” does not (an A+ counts as 4.0 just like an A), I do not use A– grades. If you earn 90% or higher, you get the A grade. I will still use A+ to recognize outstanding performance, though.

Grading Scale

GRADE	RANGE
A+	100% to 96.67%
A	96.66% to 90.00%
B+	89.9% to 86.67%
B	86.66% to 83.33%
B-	83.32% to 80.00%
C+	80.00% to 76.67%
C	76.66% to 70.00%
D	69.99% to 60.00%
F	< 60.00%

Additional Syllabus Information and Policies

Please see the following website for additional **Syllabus Resources and Policies** (https://col.st/2FA2g), QR code provided below. This page provides relevant information for the course and resources to help with various challenges that you may encounter.