Teaching Portfolio

Stephanie Dodson
Department of Mathematics
University of California, Davis

E-mail: sadodson@ucdavis.edu
Website: http://www.math.ucdavis.edu/~sdodson/

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1 Teaching Philosophy Statement

“I bring coffee from home, and I want it to be as hot as possible when I arrive to work. Should I add the milk at home, or once I get to the office? Provide a non-technical explanation with your answer.” This was a homework question assigned to me when I was first learning about differential equations and thermodynamics. We were given all the information necessary to go through the mechanics and solve for the answer, but this simple question forced us to interpret the results from a different perspective and linked the mathematical equations to everyday life. As a student, the classes I found most influential and beneficial were taught by professors who emphasized the impact of the material, not just the mechanics. As an instructor, teaching assistant, and participant in workshops on teaching pedagogy, I witnessed that students learn most effectively when they are engaged in active-learning practices, motivated by realistic examples, and are asked to think about the bigger picture. I strive to incorporate these concepts into my teaching and course design.

To date, I have taught Introduction to Abstract Mathematics (Fall 2019 & Fall 2020), Mathematical Biology (Spring 2020), and Applied Ordinary Differential Equations (Summer 2017).1 In each course, I seek to create an inclusive classroom environment by learning students names, pausing to ask for questions, encouraging discussions in class, and building flexibility into the course format.

My teaching practices have been heavily shaped by my experiences in graduate school; I was a teaching assistant during Brown University’s AAU STEM Project, Changing the Culture of Introductory STEM. The initiative focused on including student-centered learning activities into introductory courses, including problem-based recitation sessions. As a TA, I was trained to guide groups of students to correct solutions without giving away the answers; instead, I asked students to summarize their solutions and justify their methodologies. I observed that in this low-stakes environment, students became excited about the course material, were more likely to take chances, and explained concepts to their classmates – all of which resulted in deeper levels of understanding.

I firmly believe that math is best learned by doing, and active-based learning activities have become a fundamental part of my course structure. I break up lectures with quick problems and ask students to check their understanding with their neighbors. I have continued using problem-based recitation sessions with students completing worksheets in small groups. In a mid-semester feedback survey, students were asked which component of the course they found most helpful, and many responded with the group work sessions, saying “during these sessions, I get to work with students who might struggle and understand questions with me,” and they “allow students to collaborate, and put more emphasis on understanding the concepts rather than just getting a good grade on an exam.”

The spring and fall 2020 quarters were held fully online due to COVID-19. In addition to the new learning environment, students had additional unique stresses and complications in their personal lives. I structured Mathematical Biology and Introduction to Abstract Mathematics asynchronously, with online learning modules that unlocked each week with course content. Each lecture consisted of a series of short videos.2 Students commented “[lecture videos] go through the examples in a very understandable way,” and the short videos “help break down the concepts/lectures into manageable chunks.” Problem-based sessions were hosted online twice-per week via Zoom breakout rooms and provided a synchronous component as well as direct access to myself and the TAs. Students who

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1Sample assignments and syllabi from Differential Equations and Introduction to Abstract Mathematics are included in this portfolio.
2Example lecture videos available upon request.
could not attend the live meetings had the option to instead individually complete short weekly quizzes to check their understanding of the key course concepts.

My primary objective as an instructor is to build confident, critical thinkers. To help achieve this goal, I decode the underlying logic of the theory and methods as well as emphasize the broader impacts. Frequently, the hardest challenge for young mathematicians is understanding and grasping the importance of theoretical concepts and abstract language. The course Introduction to Abstract Mathematics is designed to provide a background in writing proofs and bridge the gap between lower and upper level courses. I find that students who enter the course can complete computation style problems, but do not know where to start when asked to provide a proof. In lectures and course notes I aim to explain not only the material, but also my thought process. I begin examples with scratch work that show how I first go about solving the problem, and then I demonstrate how to turn those ideas into a rigorous proof. One student commented, “it is really helpful to see you, the professor, doing problems out and the strategies you use.” To reinforce and link course concepts, I include open-ended problems in recitation and on exam review sheets, such as “discuss the relationship between equivalence relations, equivalence classes, and partitions.”

I include applications whenever possible. For example, on a differential equations midterm I provided relevant information and asked the students to write and analyze a model describing harmful algae blooms in the Great Lakes (see sample exam problem). I challenged them to write and solve differential equations for the application, and also to interpret what their results implied for the levels of toxic algae. When handing the exams back, I showed satellite pictures of algae blooms and we had a class discussion examining the model validity and implications. In doing so, the students began to think about broader impacts of mathematics and how the course material applies to careers and active areas of research. One student commented that I “always made an effort to relate back to why, the point of learning these concepts, and how the material could be applied to real life problems.”

In planning each course, I use principles of backward design to identify key learning outcomes and create assignments to monitor mastery in these areas. I assess learning through both direct and indirect methods. During group work sessions, I check-in with groups and ask each member to summarize a portion of the results for me. The recitation check-ins satisfy three objectives as their explanations provide: reinforcement of the methods used to solve the problems, practice presenting technical concepts, and give me an immediate and informal assessment of the class’ understanding or areas of confusion. Weekly homework assignments and exams furnish formal assessment of learning. I give project-based exams whenever possible, and I want to continue investigating alternatives to traditional exams. In Mathematical Biology, the take-home exams included options to either analytically compute and interpret bifurcations in neural models or to numerically simulate and describe a pair of coupled neurons. In the final group project, students researched topics of their interest and presented their findings to the class. Many groups connected the class material to the ongoing pandemic and investigated epidemic models.

I have advised three undergraduate students and co-advised one graduate student in research and employed many of these same philosophies. I believe that a well-rounded skill set is necessary for students to be successful in their future endeavors. Thus, as a research advisor I aim to illustrate how to apply skills learned in the classroom, but also prioritize building organizational, presentation, and communication skills. My advisees and I discuss how to make coherent figures, best practices for commenting code and organizing results, and the formats of presentations. I listen to each student’s career goals and incorporate the relevant skills. My current undergraduate researcher is interested
in careers in data science, so as part of her project we learned and implemented clustering methods.

I believe that there is not a single best class format, as every course will have a different atmosphere due to the unique students, class size, and content. Therefore, I strive to be fluid and structure courses with a variety of active-learning practices to cultivate critical thinking and best benefit all learners. My teaching philosophies originated from my experiences as a TA, but have continued to evolve as I participated in workshops and semester long courses on inclusive teaching practices offered by the Brown University Center for Teaching and Learning and the Center for Educational Effectiveness at UC Davis. As I gain more experience, I will continue to reevaluate my teaching goals and pedagogies along with actively participating in discussions, workshops, and seminars on inclusive teaching practices.
2 Teaching Experience

2.1 Undergraduate Courses Taught

- **Mathematical Biology, UC Davis, Spring 2020 (online)**
  Mathematical Biology is a special topics course designed for advanced undergraduate students. The primary objective of the course was to introduce students to an array of models and analytic techniques commonly used within the mathematical biology community, with a large focus on linking observed behaviors to the mathematical model. Much of the course utilized applications from neuroscience and specific topics included qualitative analysis of ODE systems, bifurcation analysis, simulation of ODE models using Runge-Kutta methods, and a short section on discrete models.

  This course was taught online during COVID and the format consisted of video lectures, homework assignments, midterm exams, and a group based final project.

- **Introduction to Advanced Mathematics, UC Davis, Fall 2019 & Fall 2020 (online)**
  The course serves as an introduction to the fundamentals of mathematical thinking and clear writing of mathematical arguments. Specific topics included proofs by contradiction, contrapositive, and induction; elementary set theory; properties of functions and inverses; and cardinality of sets. The class is typically a mixture of math, computer science, engineering, and other technical majors.

  I have taught this course in person (Fall 2019) and online due to COVID (Fall 2020). The syllabus and example assignments from the online Fall 2020 are included in the Sample Course Materials section.

- **Applied Ordinary Differential Equations, Brown University, Summer 2017**
  I was the lead instructor of Applied Ordinary Differential Equations which provides an introduction to the behavior and theory of scalar and systems of Ordinary Differential Equations and their applications. There were 14 students of a variety of backgrounds in this summer course, which had a condensed 7-week schedule but still covered all topics of the regular 16-week fall/spring version of the course. The course format consisted of lectures and student-centered problem-based learning recitation sessions.

  Examples of course materials that I used and designed are included in the Sample Course Materials section.

2.2 Teaching Assistant Positions

- **Applied Ordinary Differential Equations, Brown University, Fall 2015**
  This undergraduate course provides an introduction to understanding the behavior of scalar and systems of Ordinary Differential Equations and their applications. There were more than 60 undergraduate students in the course; with concentrations primarily in applied math, math, physics, and other STEM fields. The course format consisted of weekly lectures and problem-based recitation sessions.

  As a TA, my role was to facilitate recitation sessions, hold weekly office hours, exam review lectures, and grade assignments and exams. This course was part of Brown University’s AAU STEM Project, Changing the Culture of Introductory Science, which focused on incorporating student-centered problem-based learning sessions to increase student performance. As part
of this program, I received training to lead effective recitation sessions and office hours, and weekly feedback on my interactions with students (see AAU STEM Project section for full details).

- **Methods of Applied Mathematics I, Brown University, Spring 2016**
  This undergraduate course provides an introduction to first and second order Ordinary Differential Equations, including how to solve equations, the Laplace Transform, and basic numerical methods. The course content is tailored to engineering applications. The more than 40 undergraduate students in the course were studying a variety of STEM fields, with most students concentrating in engineering.

  As a TA, my role was to facilitate problem-based recitation sessions, hold office hours and exam review lectures, grade assignments and exams, and write homework solutions. I was the lead TA and created the worksheets for the weekly recitation sessions using principles of backward design, studies from active-based learning, and my experience as a TA in the Brown University AAU STEM Project. I also guest lectured for two regular class sessions.

### 2.3 Other Teaching Experiences

**Guest Lectures:**

- **Applied Partial Differential Equations II, Fall 2016, Brown University**
  Two lectures on topics from complex analysis. Material based off of instructors notes and course text.

- **Topics in Chaotic Dynamics, Spring 2018, Brown University**
  Three lectures on phase plane dynamics, conservative and reversible systems, and period-doubling bifurcations. Material based off of instructors notes and course text.

- **Methods of Applied Mathematics, Fall 2019, University of California, Davis**
  One lecture in a graduate level course on the connection of traveling waves in partial differential equations, phase plane dynamics, and heteroclinic connections. Material based off of instructors notes.

- **Calculus for Biosciences, Winter 2020, University of California, Davis**
  Two lectures in a calculus course designed for students majoring in the biosciences. Topics included definite integrals and introduction to differential equations.
3 Sample Course Materials: Ordinary Differential Equations

The following sections contain example syllabus, goals, worksheets, and problems for an introductory course on applied ordinary differential equations. Material was used in, or adapted from, a 2017 summer course that I taught at Brown University.

3.1 Course Syllabus

Syllabus follows Brown University guidelines and has been updated to reflect the timeline of a fall/spring semester course rather than a condensed 7 week summer schedule.

APMA 0350: Applied Ordinary Differential Equations

<table>
<thead>
<tr>
<th>Class Time:</th>
<th>MWF, 9-10 AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructor:</td>
<td>Stephanie Dodson, <a href="mailto:Stephanie_Dodson@Brown.edu">Stephanie_Dodson@Brown.edu</a></td>
</tr>
<tr>
<td>Office:</td>
<td>170 Hope Street, Room 213</td>
</tr>
<tr>
<td>Office Hours:</td>
<td>Tuesday 1-2 pm, Thursday 3-4 pm</td>
</tr>
<tr>
<td>Course Website:</td>
<td>Canvas</td>
</tr>
</tbody>
</table>

Course Description

This course provides a comprehensive introduction to the qualitative and quantitative theory of ordinary differential equations. Students will see how applied mathematicians use differential equations to solve practical problems in biology, chemistry, economics, and physics. The course will focus on building the rigorous theoretical foundations of differential equations, and using these concepts to interpret differential equations and their results in the context of applications. Specific topics include techniques for solving linear systems of differential equations, integrating factors and separable equations, numerical approaches to solving differential equations, and phase-plane analysis of nonlinear systems.

Differential equations is a main branch of mathematics and is widely used to study and analyze topics from a variety of fields. In this class, we will start with fundamental principles and work up to analyzing models used in current research. Additionally, we will provide introduction to numerical methods commonly used in research to analyze solutions of differential equations. The course will consist of lecture, group-based problem sessions, weekly homework assignments, two midterm exams, and a final project.

Learning Outcomes

By the end of the course, students will be able to:

- Discuss existence and uniqueness of solutions to ODEs
- Analyze qualitative features of ODEs by finding and classifying equilibria
- Identify and solve scalar and linear systems of differential equations with analytical techniques
- Construct and interpret phase portraits of linear systems
- Apply techniques of linear systems to nonlinear systems
- Use numerical approaches to solve differential equations
- Write differential equations and interpret solutions in the context of applications.
Prerequisites

- Full calculus sequence
- Linear algebra (can be taken concurrently)
- No coding experience required

Class Time

I highly urge you to attend all classes. Class time will include lectures and active learning problem-based sessions, and will give you the opportunity to see the material first hand. Math is best learned by doing! The problem-based sessions are ungraded, but will help you

- In this class by enhancing conceptual understanding of the material, providing extra practice for assignments and exams, and helping you form study groups.
- Outside of this class by promoting effective communication skills of technical concepts (useful in presentations and job interviews).

Homework

Weekly homework assignments will allow you to practice the course concepts, and allow for the most direct and individualized feedback about how you are progressing as a learner.

- Assignments will be available online every Wednesday, and are due the following Wednesday at the beginning of class (9 AM).
- Late assignments will not be accepted without a legitimate excuse and prior approval.
- Students are encouraged to collaborate on homework assignments, but assignments must be written up separately and individually.
- Homework assignments must take the form of a single, stapled packed with your name and neatly written (or typed) solutions labeled with problem numbers. Solutions should show all work, not just the final answer. Assignments that do not meet these requirements will receive a 20% deduction.

Exams

Midterm exams will be two hours and be given in the evening from 6-8 pm. Midterms will not be given at any other times than these scheduled times, except in classes of illness or emergency. If a serious conflict arises, you need to contact me as soon as possible prior to the midterm, and documentation verifying the excuse will be required.

The final exam will be cumulative and held during the time scheduled by the registrar. You must see a Dean in the Dean of the College’s office for final exam excuses.

Assessment

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homework</td>
<td>30%</td>
</tr>
<tr>
<td>Midterm Exam 1</td>
<td>20%</td>
</tr>
<tr>
<td>Midterm Exam 2</td>
<td>20%</td>
</tr>
<tr>
<td>Final Project</td>
<td>30%</td>
</tr>
</tbody>
</table>

Anticipated Grading Scale

<table>
<thead>
<tr>
<th>Grade</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>90-100%</td>
</tr>
<tr>
<td>B</td>
<td>80-89%</td>
</tr>
<tr>
<td>C</td>
<td>70-79%</td>
</tr>
</tbody>
</table>

The grading scale above is subject to adjustment, however the minimum grade cut-off will not be raised. Especially in borderline cases, adjustments may take into account class and problem session participation as well as improvements in performance over the semester.
Course Materials
There is no required textbook. Course notes and homework will be posted on the course webpage. Optional text resources that will complement the course material are

- Differential Equations, Blanchard, Devaney, Hall, Published by Brooks Cole, 2011. Prices range from $30 eBook and used to $250 new.

Accommodations for Students with Disabilities
If you need accommodations for classes, assignments, or exams, please contact me and Student and Employee Accessibility Services. Website: https://www.brown.edu/campus-life/support/accessibility-services/.

Diversity and Inclusion Statement
I strive to create a learning environment that supports a diversity of thoughts, perspectives, experiences, and honors your identities. To help accomplish this:

- As a participant in class discussion and problem-based sessions, you should strive to honor the diversity of your classmates and differing viewpoints the diversity contributes.
- If you have a name and/or set of pronouns that differ from those that appear in your official records, please let me know.
- Please come talk with me if you feel your performance in the course is being impacted by your experiences outside of class, including, but not limited to, religious holidays, family emergencies, jury duty, and long-term health problems.
- I will do my best to incorporate applications from a variety of fields in the sciences and humanities. If you would like to see applications to specific fields that I have missed, let me know and I will work to include those.
- If something was said in class (by anyone) that made you feel uncomfortable, please talk to me about it.

Additional Course Policies and Expectations

- Please create a respectful learning space for your peers by arriving before the start of class and not using cell phones or computers during class time without prior approval.
- All announcements will be posted on the course webpage. It is your responsibility to check the webpage periodically for assignments and notes.
- All students are expected to comply with and uphold the principles described in the Brown University Academic Code.
- I am here to facilitate your learning; let me know if you have questions! I can always be reached by e-mail, and can schedule additional office hours.
Course Outline

**Section 1: First-Order Scalar Differential Equations**
- Qualitative methods
- Existence and uniqueness of solutions
- Separable equations
- Linear-first order equations and integrating factors
- Applications/writing scalar differential equations
- Numerical methods: Matlab and dfield

**Midterm Exam 1: Wednesday, October 3, 6-8 pm**

**Section 2: Linear Systems of Differential Equations**
- Existence and uniqueness of solutions
- Linear constant-coefficient systems of differential equations
- Linear algebra review
- Classification of equilibria and phase plane dynamics
- Applications/writing systems of differential equations
- Matrix exponential
- Linear independence of solutions and the Wronskian
- Numerical methods: Matlab and pplane

**Midterm Exam 2: Wednesday, November 14, 6-8 pm**

**Section 3: Nonlinear Systems of Differential Equations**
- Jacobian of nonlinear systems
- Classification of equilibria
- Applications to infectious disease (SIR) and Predator-Prey Models
- Numerical methods: Matlab and pplane

**Final Project: Due Friday, December 14, 5 pm**
3.2 Course Goal

One of the major course goals is for students to be able to write a system of differential equations to model a given word problem and analyze the results in the context of the application (primary learning objective of section 2). To achieve this larger goal, the students will need to master a series of smaller skills, including writing a first-order system of linear differential equations for a given problem, understanding qualitative behaviors of the system by finding and classifying the stability of the equilibria, solving a first-order linear system of differential equations, and interpreting the results in the context of the application. From my experience, turning the words into math is the hardest part for students, but it is also the part that engages and excites the students the most. I have seen that students who have met this goal leave the course with a better understanding and appreciation for math.

The example problems that follow are part of the assignment sequence designed to test mastery of these learning objectives.

3.3 Active-Based Learning Worksheet

During recitation, I ask students to complete worksheets in groups of 3 at a white board or group of desks. Meanwhile, I circle between the groups and provide hints when necessary. The students check in at the end of each problem and each group member explains a component of the answer. Below is an example worksheet, which would be assigned when the students are first learning to solve linear systems of differential equations and interpret phase planes. The questions are a bit above what the students could complete on their own at this point, but they are able to solve them when working together. The example worksheet contains two types of problems: one which steps the students through how to solve a linear system and plot the phase portrait, and one which asks the students to write, discuss, and analyze a differential equation. Recitation sheets are ungraded.
Recitation

Problem 1
Consider the following differential equation system.

\[ \dot{x} = \begin{pmatrix} 4 & 2 \\ 2 & 1 \end{pmatrix} x \]

1. Find the eigenvalues and eigenvectors of the system.

2. Write down the general solution.

3. How does the solution evolve along each eigenvector? Why?
4. Sketch the phase plane for the system.

5. Discuss your solution with your group, and then your instructor.

**Problem 2**

A small car rental company has just two distributors; one in Providence and one in Boston. Travelers are allowed to rent a car in one city and return it in the other. The company wants to determine how to distribute their cars optimally among the two cities. Assume that 60% of the cars rented in Providence are returned in Providence, and 80% rented in Boston are returned in Boston. (Think carefully about how a car rented and returned in Providence changes the number of cars at the Providence location.)

1. Construct a differential-equation model that describes the number of cars the rental company has in Providence and Boston. Be sure to define all variables you use. It might be helpful to draw a diagram.

2. What assumptions does this model make? Are they realistic?
3. Plot the phase portrait of your model.

4. If the rental company has 30 cars total, how should they distribute them between Boston and Providence? *Hint:* You do not need to solve the system.

5. Discuss your solution with your group, and then your instructor.
3.4 Homework Problems

The homework problems range in difficulty and ask the students to think on different levels by remembering, applying, and extending their knowledge of concepts.

Problem 1 (10 Points)

Find the general solution of the differential equation

\[
\frac{dx}{dt} = \begin{pmatrix} 5 & 3 \\ 3 & 5 \end{pmatrix} x, \quad x \in \mathbb{R}^2
\]

and sketch the phase portrait.

Problem 2 (10 points)

Classify and sketch the phase portrait of the system

\[
\dot{x} = \begin{pmatrix} -1 & a - 4 \\ 1 & 3 \end{pmatrix} x
\]

depending on the value of the parameter \( a \).

Problem 3 (15 points)

Consider two ponds, A and B, with volumes 2,000 gal and 1,000 gal, respectively. The two ponds are connected by two streams, each of which flow a rate of 200 gal/day. Stream 1 flows from pond A to pond B, and stream 2 flows from pond B to pond A. There is a factory on the shores of pond A which dumps 10 lbs of pollutants into pond A each day. Additionally, plants and soil remove pollutants from each pond at a rate of 3 lbs/day.

1. Draw a compartment model diagram that describes the connected ponds and flow of pollutants.
2. Write a system of differential equations to model the pounds of pollutants in each pond. Be sure to clearly define any variables you introduce.
3. Write your system from part (2) into matrix-vector form.
3.5 Exam Problem

This problem could be used on the second midterm or final exam, and provides a formative assessment of the students’ ability to write, solve, and interpret a system of differential equations. The grading is based on a rubric, includes a lot of partial credit, and is focused on how the students approached the problem and correct reasoning.

Problem 1 (20 points) Lake Erie provides drinking water for over 12 million people, however harmful algae blooms continually threaten the water quality. The algae blooms create neurotoxins that kill fish, wildlife, and can paralyze humans, and are the biggest threat during the hot summer months. Health and environmental groups are concerned about the algae growth in Lake Erie and the potential of algae spreading into nearby Lake Ontario.

Uncontaminated (algae-free) water flows into Lake Erie at a rate of 10 cubic-miles/week. The Niagara River flows from Lake Erie to Lake Ontario at a rate of 10 cubic-miles/week. Additionally, water leaves Lake Ontario at a rate of 10 cubic-miles/week and flows into the Atlantic Ocean. Higher water temperatures in the smaller Lake Erie (volume of 100 cubic-miles) allow the algae to grow at a rate of 20% per week. In the colder water of Lake Ontario (volume of 400 cubic-miles), the algae grows at a rate of 10% per week. Let

\[ x(t) = \text{amount of algae in Lake Erie at time } t \text{ (lbs)} \]
\[ y(t) = \text{amount of algae in Lake Ontario at time } t \text{ (lbs)}. \]

1. Write a system of differential equations to model the amount (lbs) of algae in each lake. It may be helpful to draw a diagram.

2. Determine and classify the equilibria of the system.

3. Find the general solution.

4. In an effort to rid the lakes of algae, scientists are working on creating an algae eating bacteria. What is the minimum rate at which the bacteria need to eat the algae in order for both lakes to become algae free? Assume the algae eat bacteria in both lakes at the same rate. Justify your answer.
3.6 Alternative Final Exam Option

Instead of a final exam, one option is to assign a final project which takes the form of open-ended questions. The students will be graded primarily on their math, logic, and correct interpretations of their model. Prior to this assignment, the students will have completed several similar problems, although the previous problems would have guided the students through which pieces of analysis to complete. The open-ended nature of this problem allows me to see if the students know what types of analysis are appropriate and necessary in order to justify their answers.

Below is an example question, with the complete final project having 2-4 total questions.

**Final Project**

**Instructions:** Complete the following problems. These problems are open-ended, so be sure to explain your work. For each problem, include one paragraph justifying your methods, any assumptions you make, and your final answer.

1. The state of Maine has a problem with toxic arsenic in the ground water (naturally occurring due to the bedrock formation). As a result, many homeowners need to install pricey filter systems to make the water safe to drink. The Division of Public Health has set safe levels of arsenic in drinking water to be below $10 \mu g/L$.

A new filter has entered the market, which is cheaper and claims to be effective at reducing high arsenic levels to a safe level. The filter works by filtering some of the water twice, and on each pass, the filter is able to remove $5 \mu g$ of arsenic from each liter (L) of water. You work for an independent third-party consulting company that needs to validate that this product works and provide safety recommendations to the customers. Using concepts learned in this class, determine the highest level of arsenic that the filter can reduce to safe levels.
4 Sample Course Materials: Introduction to Abstract Math

The following sections contain example syllabus, learning outcomes, goals, worksheets, and problems for the course Introduction to Abstract Mathematics that I taught in Fall 2019 and Fall 2020 at the University of California, Davis. These examples are from Fall 2020, when the course was held online and organized in Canvas.

4.1 Course Syllabus

MAT 108 - Introduction to Abstract Math
Fall 2020 Sections: B01, B02, C01, & C02

Instructor: Dr. Stephanie Dodson
sadodson@ucdavis.edu

Office Hours: Mondays 10-11 am, Wednesdays 4:00-5:30 pm, Thursdays 2-3 pm

Course Website: Canvas

Group Work: B01/02: WF 1:10 - 2:00 pm
C01/02: WF 3:10 - 4:00 pm

The online course will consist of asynchronous video lectures, homework assignments, midterm and final exams, and participation through weekly group work and/or online quizzes.

Course Description

Proofs are a fundamental concept used in higher level mathematics but writing a clear, concise, and correct proof takes practice. The primary goal of Math 108 is to teach students the fundamentals of mathematical thinking and clear writing of mathematical arguments. This is a beginners exposure to the notion of proof, the language used by mathematicians, and an introduction to concepts in higher level mathematics. Learning to write proofs is a lot like learning a new language; we will learn new vocabulary and structures along the way. Mastery of this course enhances the ability to write well-organized scientific arguments and supports the development of clear analytical thinking. Most of the explanations and practice will use examples from basic set theory, combinatorics, and algebra. The topics learned in this course set the foundation for higher level mathematics courses.

Prerequisite: Completion of MAT 21B: Integral Calculus (or equivalent)

Topics

Specific course topics include:
- Propositional logic, quantifiers.
- Methods of proof: direct proof, proof by contradiction, proof by induction.
- Elementary set theory.
- Equivalence relations and equivalence classes.
- Functions: injections, surjections, bijections, inverse functions.
- Cardinality: finite sets, countable sets, uncountable sets.

Video Lectures

All class lectures will be asynchronous and consist of short, pre-recorded videos. Videos and notes for the full week will be posted as a Canvas module every Monday by 9AM.
Homework
Weekly homework assignments will allow you to practice the course concepts, and allow for the most direct and individualized feedback about how you are progressing as a learner. Homework will count for 30% of the final course grade.

- Assignments will be available online every Monday and are due Wednesday the week after (9 days later) by 12 PM (noon) PT.

- Students are encouraged to (remotely) collaborate on homework assignments, but assignments must be written up separately and individually.

- Homework assignments will be uploaded as a PDF to Gradescope and must have neatly written (or typed) solutions labeled with problem numbers. On Gradescope, please select which pages correspond to each problem. Solutions should show all work, not just the final answer. Assignments that do not meet these requirements will receive a 20% deduction.

- Late assignments will not be accepted without prior approval. Please communicate with me as early as possible to make appropriate arrangements.

- By filling out surveys about the course and quarter, you will have the opportunity to replace your two lowest homework grades. Links to the surveys will be available prior to submitting each midterm.

Participation
Students will have four opportunities each week to participate and may choose from attending group work sessions or completing quizzes. Math is best learned by doing, and these options are designed to bridge the gap between the material and examples given during video lectures and problems on homework assignments. Participation will count for 20% of the final grade.

1. **Group Work Sessions**: Attend twice weekly ungraded problem-based sessions on Wednesdays and Fridays at scheduled class time and work on problem sets in small groups. Group work sessions will be hosted with Zoom breakout rooms and worksheets posted on Canvas. There will be roughly 18 problem-based sessions, and attending and actively engaging in a group work session will earn you 3 participation points. Unless given approval, please attend your assigned time slot based on class section. Additional group work guidelines are available on Canvas.

2. **Online Quizzes**: Completion of two weekly Canvas quizzes due Wednesdays and Fridays. Each of the roughly 18 quizzes will be graded on a 0-3 point scale, for a maximum of 54 points.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Clear response, shows comprehension and effort, contains minor errors</td>
</tr>
<tr>
<td>2</td>
<td>Demonstrates comprehension and shows effort, contains major errors</td>
</tr>
<tr>
<td>1</td>
<td>Minimal effort/insufficient response</td>
</tr>
<tr>
<td>0</td>
<td>No submission</td>
</tr>
</tbody>
</table>

Scores will be based on the number of participation points. However, you cannot earn more than 6 points per week.
Participation scores will be assign based on the following table

<table>
<thead>
<tr>
<th>Total Participation Points</th>
<th>Participation Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>48+</td>
<td>100%</td>
</tr>
<tr>
<td>42 - 47</td>
<td>90%</td>
</tr>
<tr>
<td>36 - 41</td>
<td>80%</td>
</tr>
<tr>
<td>30 – 35</td>
<td>70%</td>
</tr>
<tr>
<td>24 - 29</td>
<td>60%</td>
</tr>
<tr>
<td>15 - 21</td>
<td>50%</td>
</tr>
<tr>
<td>&lt; 15</td>
<td>0%</td>
</tr>
</tbody>
</table>

Exams
The two midterm exams will be take-home and available on Canvas. You will have 55 minutes to complete the exams on the scheduled day. Exams will be open notes and textbook, but collaboration or external sources are not allowed. If a serious conflict or family emergency arises, please contact me as soon as possible to make alternate arrangements.

- **Midterm 1**: Friday, October 30
- **Midterm 2**: Monday, November 23

The final exam will be cumulative and held on the day scheduled by the registrar.

**It is intended that all exams will be take-home and taken at the time of your choice on the exam date. This format relies on high academic integrity of all students. Exam format is subject to change if this flexibility is abused.**

Assessment

<table>
<thead>
<tr>
<th>Homework</th>
<th>30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participation</td>
<td>20%</td>
</tr>
<tr>
<td>Midterm Exam 1</td>
<td>15%</td>
</tr>
<tr>
<td>Midterm Exam 2</td>
<td>15%</td>
</tr>
<tr>
<td>Final Exam</td>
<td>20%</td>
</tr>
</tbody>
</table>

Course Materials
The required course textbook is:

  - Either 7th or 8th edition acceptable
  - 8th edition available on Canvas through Equitable Access

The course textbook is there to help you and will provide additional examples not covered in class. Homework will be posted on the course webpage.

Additional Course Tools

- **Office Hours**: Office hours will be hosted live on Canvas using the built in Zoom video conferencing tool. The instructor and TA office hours are a great place to come ask questions about course materials, receive guidance on homework problems, and ask about math research! Office hours will not be recorded. Additional office hours can always be made by appointment - just ask!
• **Campuswire:** We will use Campuswire as a course discussion board. Students are encouraged to post questions about logistical and course materials here so that other students have the opportunity to view and answer them.

**Accommodations for Students with Disabilities**
Any student with a documented disability (e.g. physical, learning, psychiatric, vision, hearing, etc.) who needs to arrange reasonable accommodations must contact the Student Disability Center (SDC). Faculty are authorized to provide only the accommodations requested by the SDC. If you have any questions, please contact the SDC at (530) 752-3184 or sdc@ucdavis.edu. *If you are given any accommodations, please let me know as soon as possible so that I have time to make appropriate arrangements.*

**Diversity and Inclusion Statement**
I strive to create a learning environment that supports a diversity of thoughts, perspectives, experiences, and honors your identities. To help accomplish this:

- As a participant in class discussion and problem-based sessions, you should strive to honor the diversity of your classmates and differing viewpoints the diversity contributes.
- If you have a name and/or set of pronouns that differ from those that appear in your official records, please let me know. Additionally, feel free to change your Zoom name to your preferred name and pronouns.
- Please come talk with me if you feel your performance in the course is being impacted by your experiences outside of class, including, but not limited to, religious holidays, family emergencies, jury duty, and long-term health problems.
- If something was said in class (by anyone) that made you feel uncomfortable, please talk to me about it.

I recognize that many of you have additional responsibilities, stresses, and unique situations at this time. When possible, I encourage you to adhere to the timelines outlined in this syllabus. Appropriate extensions will be given on a case by case basis. If some aspect of this class format is unpractical for you and your current situation, please talk to me about it! In order to best help you, I need you to communicate with me as early as possible so that we can make appropriate accommodations.

**Additional Course Policies and Expectations**
- Please create a respectful learning space for your peers by arriving on time and prepared to group-work sessions.
- All announcements will be posted on the course webpage (Canvas). It is your responsibility to check the webpage periodically for assignments and notes.
- Emails to me will be answered within 24 hours on weekdays and 48 hours on weekends. Please be respectful of your TA and instructor by being courteous and professional in emails.
- All students are expected to comply with and uphold the principles described in the [UC Davis Code of Academic Conduct](#).
- I am here to facilitate your learning; let me know if you have questions! I can always be reached by e-mail, and can schedule additional office hours.
Course Outline
Subject to slight modification. Check Canvas page for updates.

<table>
<thead>
<tr>
<th>Week(s)</th>
<th>Sections</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 3</td>
<td>1.1 – 1.6</td>
<td>Introduction and course policies. Logic and proofs. Lighter on initial material with emphasis on proof techniques.</td>
</tr>
<tr>
<td>3 – 5</td>
<td>2.1 – 2.5</td>
<td>Sets and induction. Emphasis on mathematical induction and equivalent principles.</td>
</tr>
<tr>
<td>6</td>
<td>3.1 – 3.3</td>
<td>Equivalence relations and partitions.</td>
</tr>
<tr>
<td>7 – 8</td>
<td>4.1 – 4.4</td>
<td>Functions. Emphasis on onto and 1-1 functions.</td>
</tr>
<tr>
<td>9-10</td>
<td>5.1 – 5.3</td>
<td>Cardinality, Do in full detail up to Theorem 5.3.8, which requires the Axiom of Choice.</td>
</tr>
<tr>
<td></td>
<td>5.4 – 5.5</td>
<td>Order of cardinals, comparability. Emphasis on section 5.4, but omit proof of Cantor-Schroeder-Bernstein Theorem and do 5.5 lightly.</td>
</tr>
</tbody>
</table>

4.2 Course Goal
This course is the first time that many students encounter proofs. One major goal of the course is to get the students confident and comfortable writing a variety of proof styles, including direct proofs, proof by contradiction and contrapositive, and induction. When given a statement to prove, students often have trouble determining which type of proof to use. In order to confidently write proofs, students first need to master a series of intermediate skills, including writing propositional forms and denials, understanding the truth sets of statements with quantifiers, and knowing the structures and pros/cons of the different proof methods. Topics throughout the course focused on learning and proving properties of set theory, relations, functions, and cardinality of sets. The example problems that follow are part of the assignment sequence designed to test mastery of this learning objective.

In addition to topics stated in the syllabus, the full set of student learning objectives was posted on Canvas. Each week the relevant learning objectives were included in the weekly module and again summarized before exams.

4.3 Weekly Participation Check
Each week, the students were required to complete two of four options to participate and check their learning; they could attend two group work sessions, complete two quizzes, or a complete a mixture. These options were chosen to get students actively thinking about the math throughout the week and keep students on pace in the online environment. Participation options were low-stakes chances to test their understanding and graded solely based on attendance and completion of quizzes. Problems were chosen to bridge the gap between examples given in class and those on the homework.

Below are example problems from the group work sessions and quizzes throughout the quarter. The first problem emphasizes propositional forms and quantifiers. Students are told to use proof by contradiction in the second problem, and in the third that scaffolding is removed and students need to identify by themselves which proof method to use. Additionally, throughout the course new mathematical material is added in and the students need to utilize new definitions in their proofs.
Problem 1
Discuss the difference between the following two statements and determine if each is true or false.

1. For all \( n \in \mathbb{Z} \), there exists an \( m \in \mathbb{Z} \) such that \( m + n = 0 \).
2. There exists an \( m \in \mathbb{Z} \) for all \( n \in \mathbb{Z} \) such that \( m + n = 0 \).

Problem 2
Use proof by contradiction to prove the following statement:

If \( n \in \mathbb{N} \), then
\[
\frac{n}{n+1} > \frac{n}{n+2}.
\]

Problem 3
Let \( A \) and \( B \) be two sets. Show that \( \emptyset \notin \mathcal{P}(A) \setminus \mathcal{P}(B) \).

4.4 Homework Problems
The homework problems range in difficulty and get students to complete proofs on their own by gradually removing the scaffolding throughout the quarter. Sample problems from the course are included below that show this progression.

Problem 1
Determine if the statement is true or false, and translate into English. The universe of discourse is all positive real numbers.
\[
\sim (\forall x)(\exists y) (xy = 1)
\]

Problem 2
Write a proof by contradiction to prove that every point on the line \( y = 6 - x \) is outside the circle with radius 4 and center \((-3, 1)\).

Problem 3
Prove that there exists is a natural number \( K \) such that \( \frac{1}{r^2} < 0.01 \) whenever \( r \) is a real number larger than \( K \).

Problem 4
Prove that if a real-valued function \( f \) is increasing, the \( f \) is injective.

4.5 Exam Problem
Problem: Find the cardinality of the set \( \mathbb{R} \setminus \mathbb{Q} \). Prove your answer.

This problem could be used on a second midterm or final exam as it provides an assessment of several course skills and topics. First, the student needs to understand that the real and rational numbers are sets, understand the set minus, and the concept of cardinality. Finally, the student needs to decide what method they are going to use to prove the statement. It can be shown that the cardinality is \( c \) directly by finding a bijection between \( \mathbb{R} \setminus \mathbb{Q} \), or by contradiction using properties of unions of uncountable sets.
5 Evidence of Effective Teaching and Student Learning

Below are summaries of student evaluations of my performance as an instructor and as a teaching assistant. Full teaching evaluations available upon request.

5.1 Instructor Course Evaluations

At the end of the quarter, students at University of California, Davis are asked to answer 11 questions on a 5-1 scale corresponding to Excellent (5), Very Good (4), Satisfactory (3), Fair (2), and Poor (1). Responses to selected questions from completed courses are included in Figure 1.

Introduction to Abstract Mathematics: Fall 2019
Overall instructor effectiveness
Clarity of course objectives
Effectiveness of class presentations

Mathematical Biology: Spring 2020
Overall instructor effectiveness
Clarity of course objectives
Effectiveness of class presentations

Figure 1: From top to bottom, bars indicate responses to (1) Overall teaching effectiveness of instructor, (2) Clarity of course objectives and organization, and (3) Effectiveness of style and methods of class presentation.

Introduction to Advanced Mathematics, UC Davis, Fall 2020
Course is ongoing and end of quarter reviews are not yet available. However, below are a sampling of responses from a mid-quarter anonymous survey.

“I really do appreciate the way this course is taught ... It allows students to collaborate, and puts more emphasis on understanding the concepts rather than just getting a good grade on an exam. I definitely feel as though I am learning more efficiently rather than spending hours on end on homework, or understanding material.”

“The smaller twice-a-week quizzes and longer, weekly homework assignments work well together, keeping me always engaged with the class. The difficulty of the homeworks is especially nice, where it feels like it’s harder than the quizzes, but not too hard to not be able to figure the questions out, staying in a nice zone of difficulty.”

Mathematical Biology, UC Davis, Spring 2020

23/32 students completed the end of quarter evaluation. Examples of written comments from the course are below.

“This class really opened my eyes to what was possible in mathematics. Dr. Dodson made easy to follow videos that made learning akin to in-person lectures. Great course and great instructor.”
“I thoroughly enjoyed this course with Stephanie. She handled the abrupt transition to online learning gracefully. I learned so much, and the homeworks were challenging and educational. Office hours have been reliably helpful when I’ve attended.”

“Her lectures are informative and well structured. I also really appreciate the problem sets as they are not usually a reiteration of the lecture material. I usually learn something more from them.”

**Introduction to Advanced Mathematics, UC Daivs, Fall 2019**

A total of 35/66 completed the end of the quarter evaluation. Examples of written comments from the course are below.

“Her lectures are always simulating and interesting. She covers nearly most details of the course and she always gives enough example and illustration to make sure most students understand the knowledge.”

“Very open to questions, goes over material meticulously.”

**Applied Ordinary Differential Equations, Brown University, Summer 2017**

A total of 9/15 students completed the evaluation, and were asked to rate the instructor effectiveness given options Very Effective, Effective, Somewhat Effective, Ineffective, and Very Ineffective (see Figure 2).

![Pie chart showing instructor effectiveness ratings](image)

**Figure 2: APMA 0350: Instructor Effectiveness**

Students were asked to comment on the effectiveness of the course (including their own learning and what knowledge or skills the course helped them to develop), and on the effectiveness of the instructor. The majority of student commented on the their learning of writing and solving differential equations, and the clarity of my explanations and course organization. A selection of student quotes are included below.

**Comments on effectiveness of the course and student learning:**

“I learned new topics of math which I am really interested. I developed skills essential for my learning such as thinking and communicating.”
“This course helped me write differential equations to model systems and analyze them.”

“1. basic introduction of ODE 2. several interesting ways to solve them 3. interesting examples”

Comments on instructor’s overall effectiveness:

“The instructor really went above and beyond to teach well and I feel that she succeeded in making learning effective and easy.”

“She was a very clear lecturer and took the appropriate time to explain concepts thoroughly. She was easily accessible outside of class in case of questions as well.”

“Stephanie was always very prepared for class. She was clear and effective at explaining comments – at times much more so than math professors who have taught me at Brown. Her lectures were clear, and the problem sets were doable based on what we learned. She was also helpful during recitation sections, rotating between groups to check in and offer hints at the more difficult problems. She was also prompt with posting solutions to the homework, which made studying easier. Her practice review problems for exams were also extremely helpful. I enjoyed her choice to incorporate a bit of matlab in the work. She always made an effort to relate back to why/ the point of learning these concepts, and how the material could be applied to real life problems. Although at times I have considered changing my major, Stephanie really motivated me this summer to stick with applied math.”

5.2 Teaching Assistant Course Evaluations

A total of 110 students filled out teaching assistant evaluations for me, and all students who filled out the evaluation selected that they would recommend me as a TA to other students. Additionally, for rating “teaching assistant’s overall effectiveness,” no students selected Ineffective or Very Ineffective.

Applied Ordinary Differential Equations, Brown University, Fall 2015

A total of 69 students filled out the evaluation.

The majority of students commented on the clarity of my explanations, my preparation, and helpfulness during office hours. A selection of student quotes are included below.

“Steph is really helpful in sections and office hours. She helps me with categorization and generalization of scattered knowledge and has been very helpful in response to my questions.”
“Great TA - always came prepared with lecture notes - prepared good problems for practice - and always available to answer questions of students. Also explained material in a very clear way.”

“Stephanie was approachable, knowledgeable about the subject matter, and quite good at understanding and addressing points of confusion without giving too much away about how to solve homework problems. She was particularly good about following up via email after office hours (on a few occasions people would ask questions that were related to outside sources, which she would send to the people present as office hours via email).”

“Stephanie is brilliant. She really knows what she is doing and was a huge help to many students, including me. I can tell she prepared beforehand and was able to answer nearly all the questions students asked, which was impressive. She was clear and effective.”

Methods of Applied Mathematics I, Brown University, Spring 2016
A total of 45 students filled out the evaluation.

Figure 4: APMA 0330: (left) Teaching assistant availability and clarity. (right) Overall effectiveness of teaching assistant; number of student responses indicated in each wedge.

The majority of student comments commended on my organization, the clarity of my explanations, my preparation, and helpfulness during exam review lectures. A selection of student quotes are included below.

“Stephanie was extremely helpful and was always available for the students. Her explanations of complex mathematical concepts were exceptionally clear, simple and to the point. She went way beyond the expectations of a teaching assistant and always put the students’ needs before her own.”

“Stephanie did midterm reviews and she was able to concisely summarize many concepts while also talking about the reasons behind certain concepts.”

“The best TA I’ve ever had. She prepared excellent review material and was always available.”

“She’s amazing. She would prepare us for every exam so well by (1) giving a very clear, well planned-out review lecture, and (2) putting together review questions to walk us through the material outside of class when studying. I didn’t go to her recitation sections but I’ve heard that she teaches them very well too.”
6 Pedagogical Training

6.1 Center for Educational Effectiveness, UC Davis

The Center for Educational Effectiveness at the University of California, Davis offers short and extended workshops to assist in creating an inclusive and equitable classroom. I have attended several short workshops throughout the Center, as well as the three-day 2020 Student Learning Outcomes Symposium, and the 2020 Summer Institute on Teaching and Technology (SITT). Many of these workshops have focused on multiple modes of engagement and equity in assessment, often with remote learning and the pandemic in mind.

6.2 Sheridan Center for Teaching and Learning, Brown University

The Sheridan Center for Teaching and Learning at Brown University offers semester-long certificate programs and individual workshops to promote effective teaching practices. I have participated in three certificate programs (described below) and attended additional workshops to learn about inclusive classroom design and improve my teaching practices.

Reflective Teaching Seminar, Fall 2015

This introductory seminar highlighted evidence-based inclusive teaching practices, student engagement, principles of learning design, and reflection upon my own learning experiences and teaching practices. As part of this certificate, I was observed while giving a lecture about my research and received feedback on how to improve the structure and clarity of my presentation.

Teaching Consultant Program, Fall 2017-Spring 2018

In this certificate, I was trained to become a Teaching Consultant for the Sheridan Center. I learned how to observe and provide constructive feedback on the teaching practices of diverse classrooms and subject areas. I had the opportunity to observe courses across the STEM fields and humanities, and was trained to focus on the instructor’s interaction with the students and classroom environment. During the observations, I also reflected on the differences in teaching practices across the disciplines and considered how non-standard teaching practices and assignments could benefit math classrooms. In the spring semester, the seminar focused on documenting our teaching methodologies, including writing teaching philosophy statements.

Course Design Seminar, Spring 2018

This certificate focused on composing realistic course goals and using principles of backward design to create effective forms of assessment. As part of the seminar, I developed a series of assignments for an introductory mathematics course that monitored mastery of specific learning outcomes and crafted a detailed syllabus. I also had the opportunity to reflect upon my own teaching practices and forms of assessment that I used during the 2017 summer course.

6.3 Brown University’s AAU STEM Project

As a teaching assistant for Applied Ordinary Differential Equations in Fall 2015, I was part of Brown University’s AAU STEM Project, Changing the Culture of Introductory Science. This initiative focused on incorporating student-centered learning activities, such as problem-based recitation sessions, into introductory STEM courses with the goal of improving retention and student performance.
particularly in underrepresented groups. I received training on how to facilitate effective recitation sessions and office hours.

During the recitation sessions, students completed worksheets in groups of three as myself and other teaching assistants circled between the groups. My role was to guide the students to the correct answers without telling them the answer. Instead, I was trained to ask the students directed questions and ask them to explain their methodologies. I observed that in this low-stakes environment, students were more likely to take chances and talk with and help their group members, all of which resulted in deeper levels of understanding. I used similar techniques during office hours to lead the students to the correct answers.

I was observed and received weekly feedback about my interactions with the students from a STEM education postdoctoral research associate involved in the study. I found the feedback very helpful, and it gave me an opportunity to reflect upon and better my teaching practices. The results of the project indicate the inclusive teaching practices benefited the students, and I witnessed the increased student understanding as a TA. Because of my participation in the project, I chose to incorporate student-centered problem-based learning sessions into the Methods of Applied Mathematics course that I TAed (Spring 2016) and as an instructor in Applied Ordinary Differential Equations (Summer 2017), and will continue to include similar inclusive teaching practices in future classes that I teach.