Mathematical Modeling as an Active Process
CTL Fellows 2018-19 Final Report

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Math 254 "Intro to Mathematical Modeling" plays an interesting role in the math curriculum as the unofficial capstone of the current Models and Data minor. Mathematical modeling is frequently described as "using mathematical tools to describe, analyze, and gain insight into messy, complicated, real-world problems". The interdisciplinary nature of this class, particularly within the minor, draws students from a wide variety of majors. The capstone perspective pushes these students to look deeply into a real-world topic, using mathematical tools that may have been uncomfortable for many of them cross-discipline.

I first taught this class in spring 2018 and developed a list of things that I wanted to introduce or improve in spring 2019 (and in spring 2020 when I will teach it for a third time). This list of changes became the start of my CTL Fellow project; in the end, I mainly focused on the development and implementation of a semester-long modeling project for my students to explore.

Relevant Improvements to Course Content:

The biggest change I made to the course content was to re-order the topics, with an eye towards teaching the more broadly useful topics early in the semester. We started with functional relationships and data trends, which would be useful for all project topics and applied within the other course content as the semester progressed. The overall re-ordering had the positive side effect of focusing on topics that were more familiar first, giving the students some confidence while exploring a new context for their abilities.

Modeling Project Design and Improvements:

I had several major goals for the modeling project:

1) Standardize the difficulty/feasibility of projects, while providing freedom of choice.
2) Scaffold the project work, throughout the open-ended modeling process.
3) Set clear expectations, framed by an evolving understanding of feasibility.
4) Require students to communicate clearly, both in writing and in oral presentation.

I began by introducing project topics and resources from the M3 Challenge:

> "MathWorks Math Modeling (M3) Challenge (http://m3challenge.siam.org) is an Internet-based applied math competition for high school juniors and seniors known for inspiring them to pursue STEM majors and careers."

Organized by the Society for Industrial and Applied Mathematics (SIAM) and sponsored by MathWorks (the developer of MATLAB), the M3 Challenge provides many resources which are freely available. This includes student guidebooks on how to approach a modeling problem, as well as the competition archives with old problems, winning solutions, and judges' perspectives.

I selected several old problems from the M3 Challenge as possible project prompts for my class, and allowed them to rank their preferences. Alternatively, they were also able to design their own projects with guidance from the prompts given. By working with these challenge problems, the difficulty was fairly standardized at an approachable level for this class based on its prerequisites. We also had proof that the problems were feasible and had appropriate data available for analysis.

As the students picked their topics, I provided an explanation of my grading criteria, which followed the general outline of the modeling process that they would follow, and of the report that they would submit. I set aside time in class for the students to work on their projects, and required them to meet with me twice outside of class as well. After these meetings, they submitted a draft and received feedback on the grading criteria as described. Through these interactions, I was able to scaffold the process over the course of the semester, and to discuss the expectations in a way that was clear and firm, but also flexible to the needs of the individual projects.

In addition to the project report, the students were required to present to their classmates during the final exam period. This was a good way to end the semester, as an opportunity to share their work and interesting results in an informal way.

General Outcomes and Takeaways:

I was generally pleased with the improvements in this iteration of the class. I did need to trim additional course content in order to make the in-class project time fit into the schedule, but since the students used that time positively, it seems to have been a worthwhile change. The groups also used their meetings with me well, by sharing their progress, expressing their projects' challenges, and setting progressive goals for their work.

The projects also had a much clearer pathway to success, while still allowing for significant freedom of topic choice. Some groups chose M3 Challenge prompts, while others developed project ideas based on their own interests, taking cues from the provided prompts in order to meet the project expectations. In the future, I would be more active in vetting the student-designed project ideas over time to ensure their reasonability.

Multiple students commented that they found their projects quite interesting, and that they felt they learned more about the modeling process and its challenges through their experience. Engagement in the project was definitely improved. Perhaps the most

fun outcome was during the project presentations: I challenged the class to help me ensure that each group was asked at least one audience question, and they heartily obliged!

Further Implementation Goals:

In the future, with the retirement of the Models and Data interdisciplinary minor and the introduction of the Applied Math disciplinary minor, I expect that the curricular role of Math 254 will change in some ways. While the nature and intent of the class will remain the same, the group of students drawn to take this class may evolve, allowing for deeper exploration of specific topics. My goal is to manipulate the class through the start of these changes, and leave it in a versatile position for future years.

Specific further changes to be made include:

- ***Expansion of project prompts*** to include contest problems from COMAP's Mathematical Contest in Modeling (MCM) and Interdisciplinary Contest in Modeling (ICM): https://www.comap.com/undergraduate/contests/index.html. These are slightly higher-level and more diverse than the M3 Challenge problems, but provide fewer additional resources and may be more variable in difficulty.
- ***Discussion with colleagues*** to brainstorm further interdisciplinary project ideas.

- ***Guidelines for student-developed projects***: see note in "general outcomes" above.
- ***Adjusting the balance of content & open-ended process:*** the class provides mathematical and technological tools for modeling, but also is designed around the modeling process, which is open-ended and highly variable based on the real-world problem. Finding this balance, particularly in the context of classroom time and assessments, is a moving target.

CTL Fellows Wrap-Up:

Working with the CTL Fellows as part of this program was of significant benefit to my pedagogy this year. I made connections with colleagues across the campus, and discussed projects even more closely with a few of the other fellows. I was reminded that even when our fields are drastically different, we can still share more ideas than we might immediately realize.

Perhaps the most important advice I received was to "dream big, but start small" – the same lesson as my students learn about mathematical modeling!