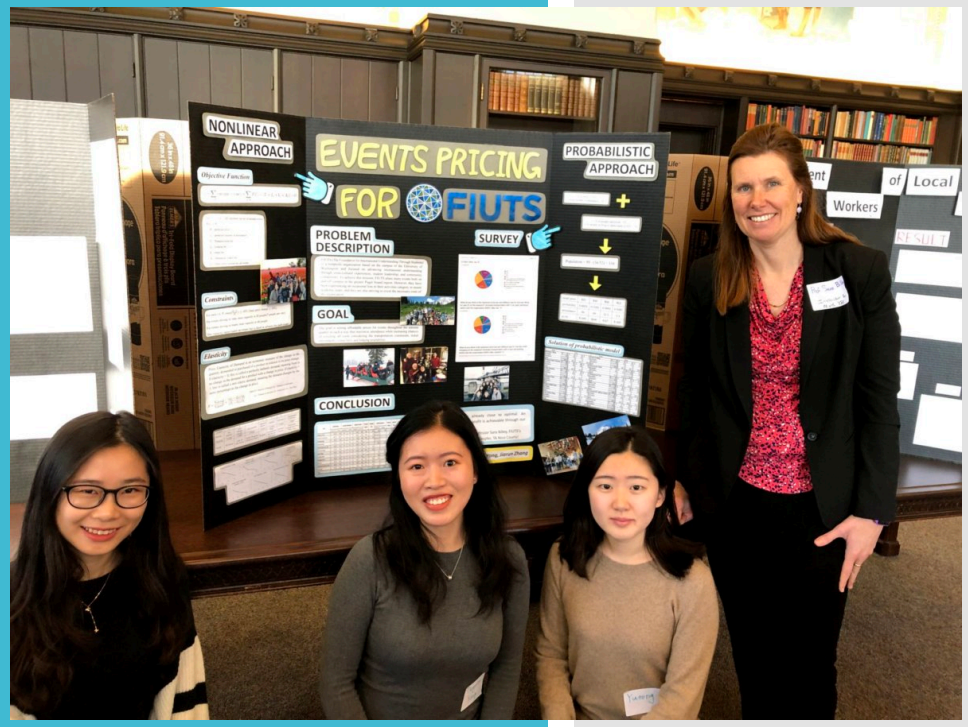
Incorporating Service-Learning into Math Courses

case studies in applying modern math to solve problems in the community

By Sara Billey

Math Dept. University of Washington



Team: Jiarun Zhang, Dara Yang, and Yutong Li,

Inspiration:

Amy Smith

Director D-Lab at MIT

https://www.ted.com/talks/amy_smith_shares_simple_lifesaving_design

https://d-lab.mit.edu/. "Smith now focuses on Creative Capacity Building"

How can math improve the community?

- By solving problems!

How can math improve the community?

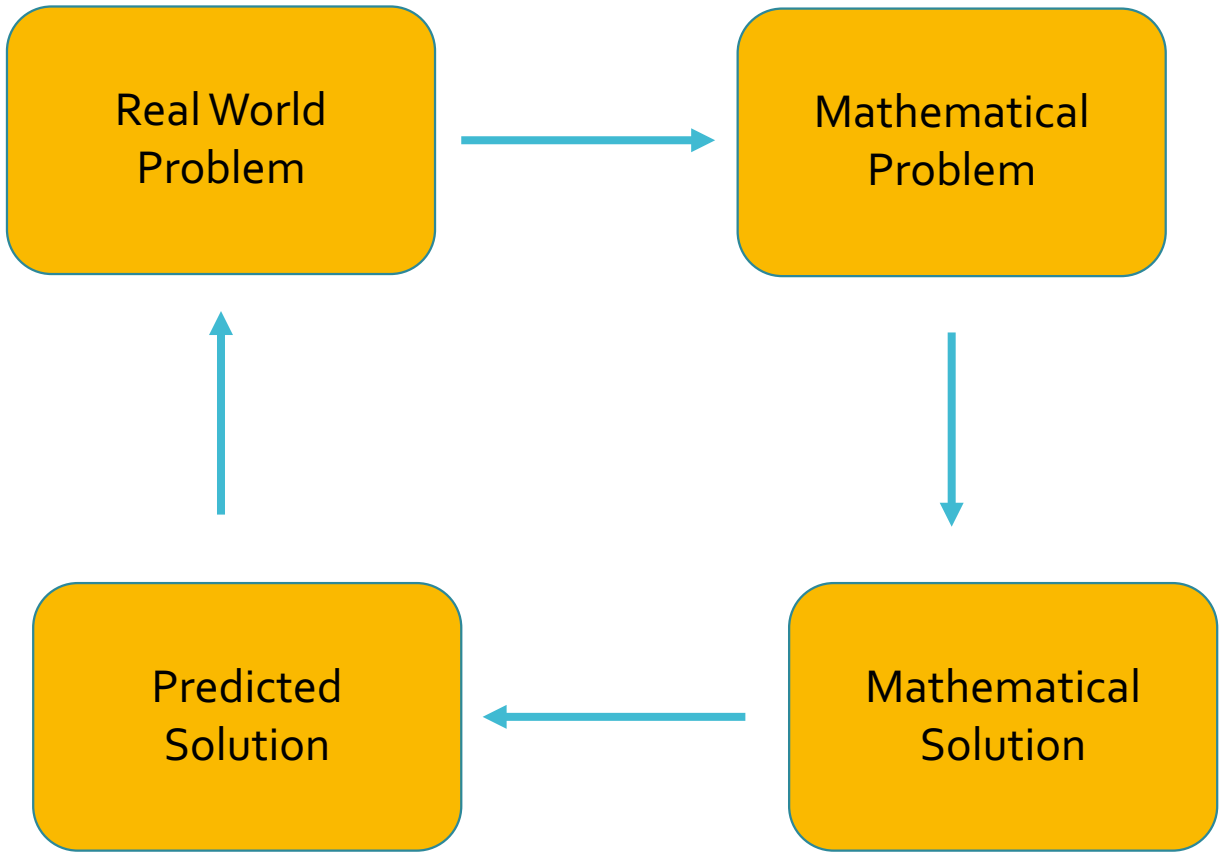
By solving decision problems:

- Calculating sufficient strength of a bridge so it won't collapse in high wind, with many cars, bike and pedestrians.
- Weather prediction saves lives.
- Delivering packages for Amazon, UPS, Fedex etc quickly.
- Creating fair districts for voting and detecting gerrymandering.
- Extending the number of people involved in kidney transplants.
- Searching the web with high likelihood of finding the right website.

How can math improve the community?

- I teach a class in **Discrete Mathematical Modeling.**
- **Discrete** means **not continuous** like people, boxes, and tasks.
- **Modeling** means we are solving decision problems through formulas that match our goals. Sometimes it is hard to write down real world goals in variables and formulas.
- We practice the 4-stage modeling cycle.

4-Stage Modeling Cycle



4-stage Modeling cycle

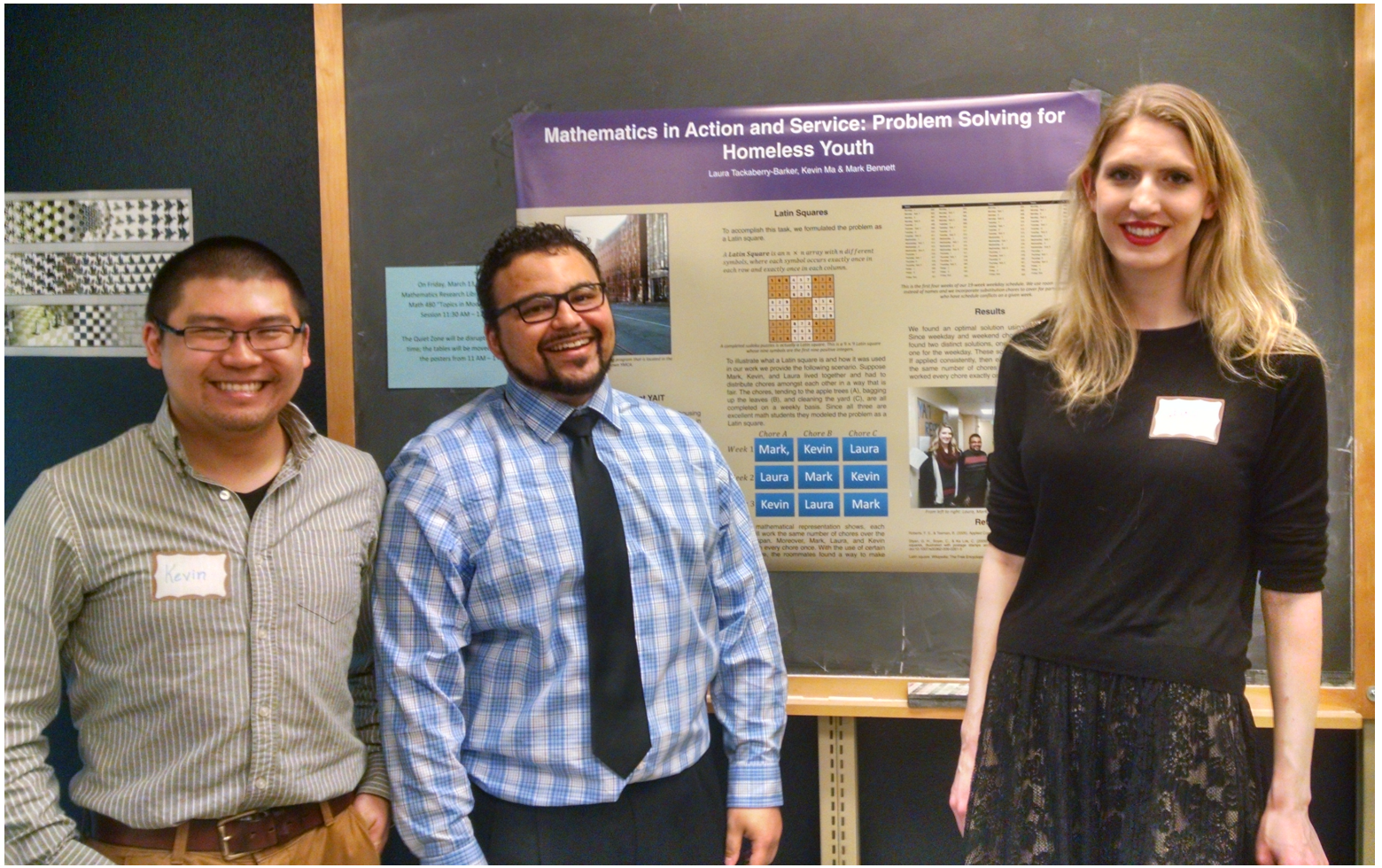
- Mathematical modeling is the process that takes real world problems, translates them into quantitative/mathematical terms, uses mathematics to make future predictions and suggest improvements, interprets the predictions back into every day terminology, tests the predictions/improvements, updates the model based on the tests, and repeats the process in hopes of finding even better solutions.

- "All models are wrong, but some are useful!" -- George Box

How can math improve the community?

- For class, students are required to do written projects.
- Now, projects must come from the community: students find nonprofit organizations, small businesses, churches, and clubs on the UW campus which are wrestling with decision problems they would like to solve in an optimal way but they have constraints and tradeoffs.
- We provide models for the data and recommended solutions!
- We teach the community partners and general public about the math involved through a poster session and further discussions.

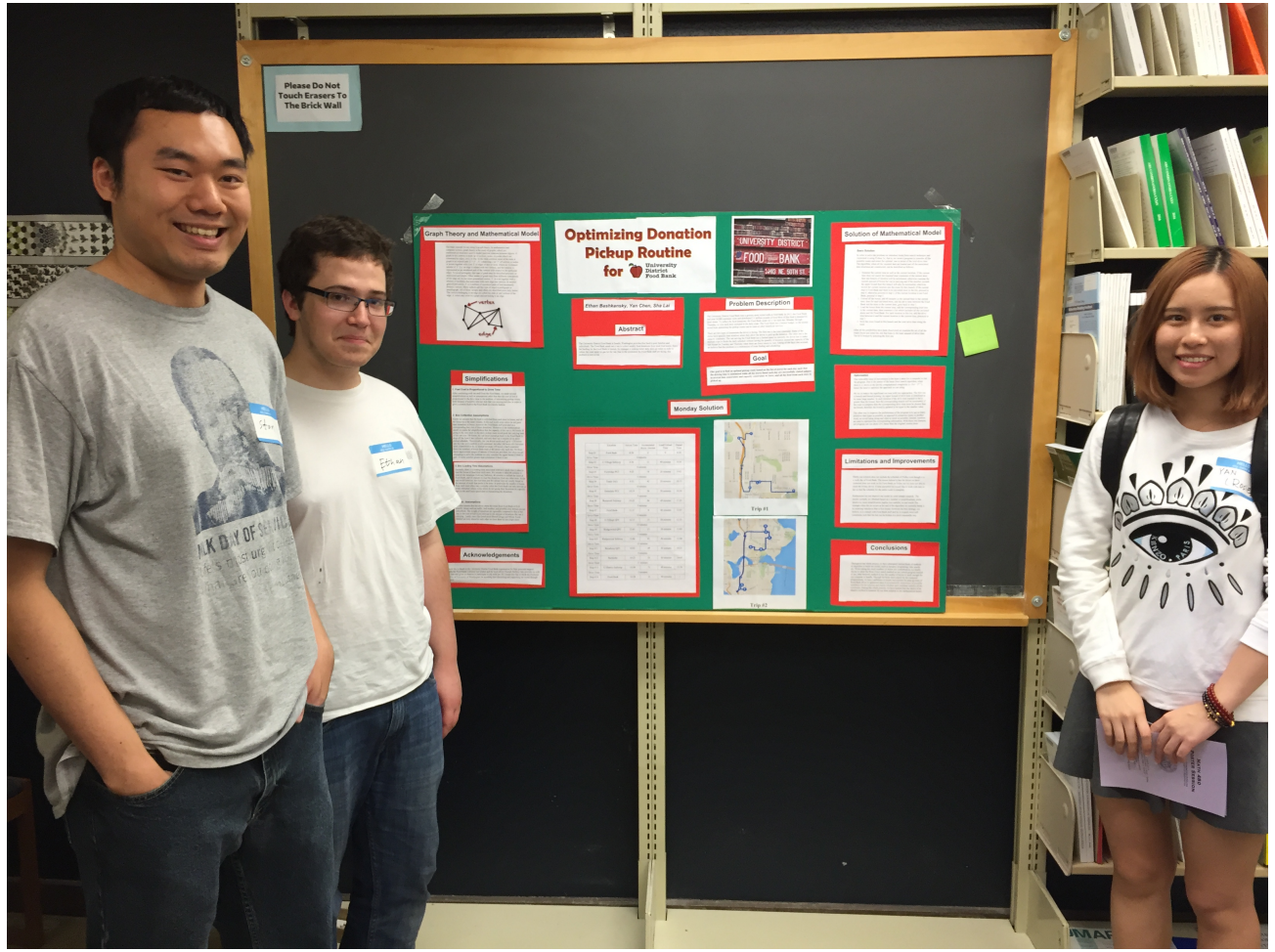
Tasks at YAIT: Young Adults in Transition



Team: Kevin Ma, Mark Bennett, and Laura Tackaberry Barker

How can we assign and rotate jobs at YAIT in such a way that everyone feels they are treated fairly and still have flexibility for occasional interruptions in the schedule? Ans: Use Latin squares!

Donation Pickup for the University Food Bank

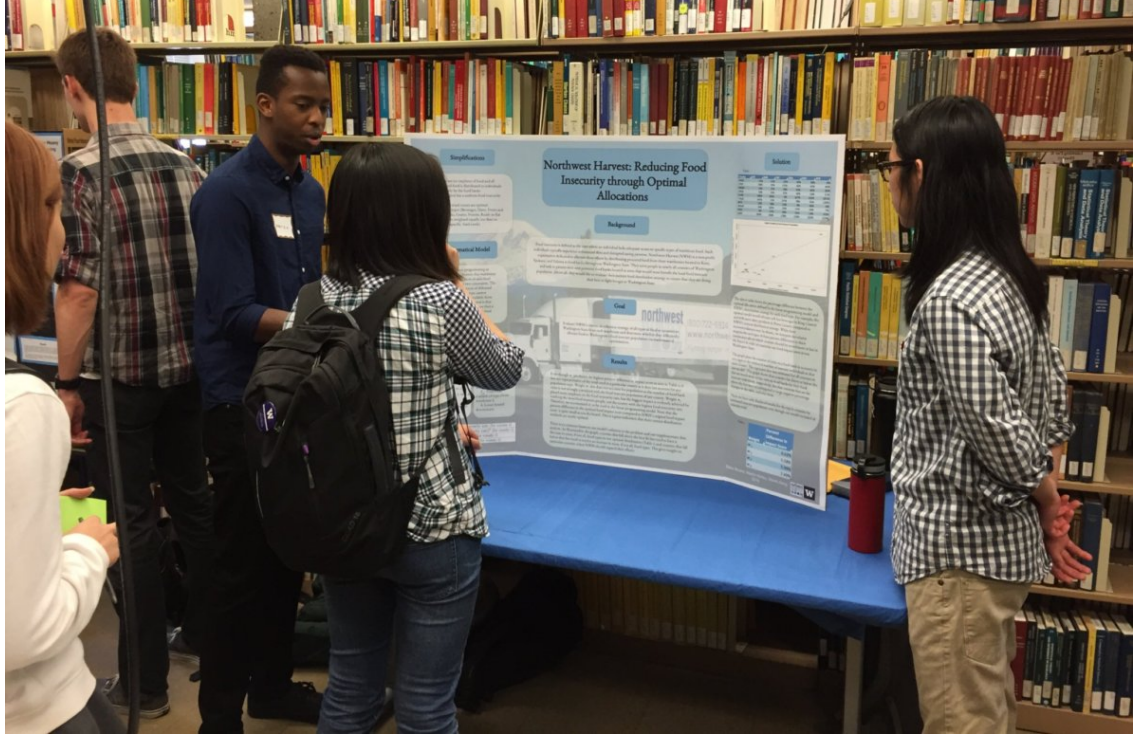


Team: Sha Lai, Ethan Bashkansky, and Yan Chen

How can we most efficiently route a truck to pickup donated food from area grocery stores in such a way as to meet the required timing constraints? Answer: linear programming!

Reducing Food Insecurity

Through Optimal Allocations

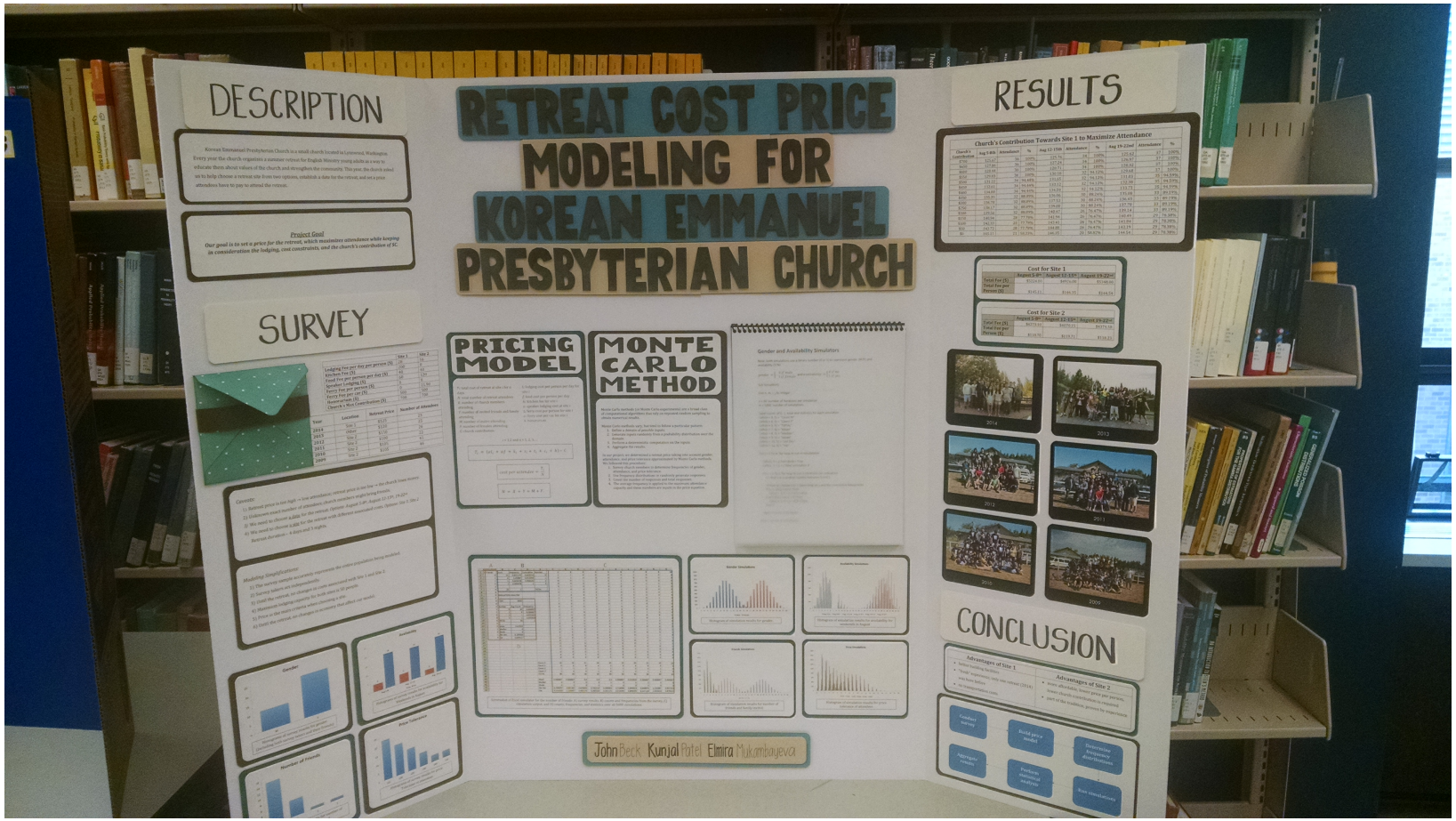


Team: Blake Bryant, Martin Kinisu, and David Zeng

Northwest Harvest is a nonprofit organization dedicated to fighting hunger throughout Washington State. They allocate donated foods and resources to people in need from three warehouses located in Kent, Spokane, and Yakima.

What is the optimal allocation of food of all types from the three warehouses that should be sent to each food bank in the state in order to minimize food insecurity? Ans: Linear Programming.

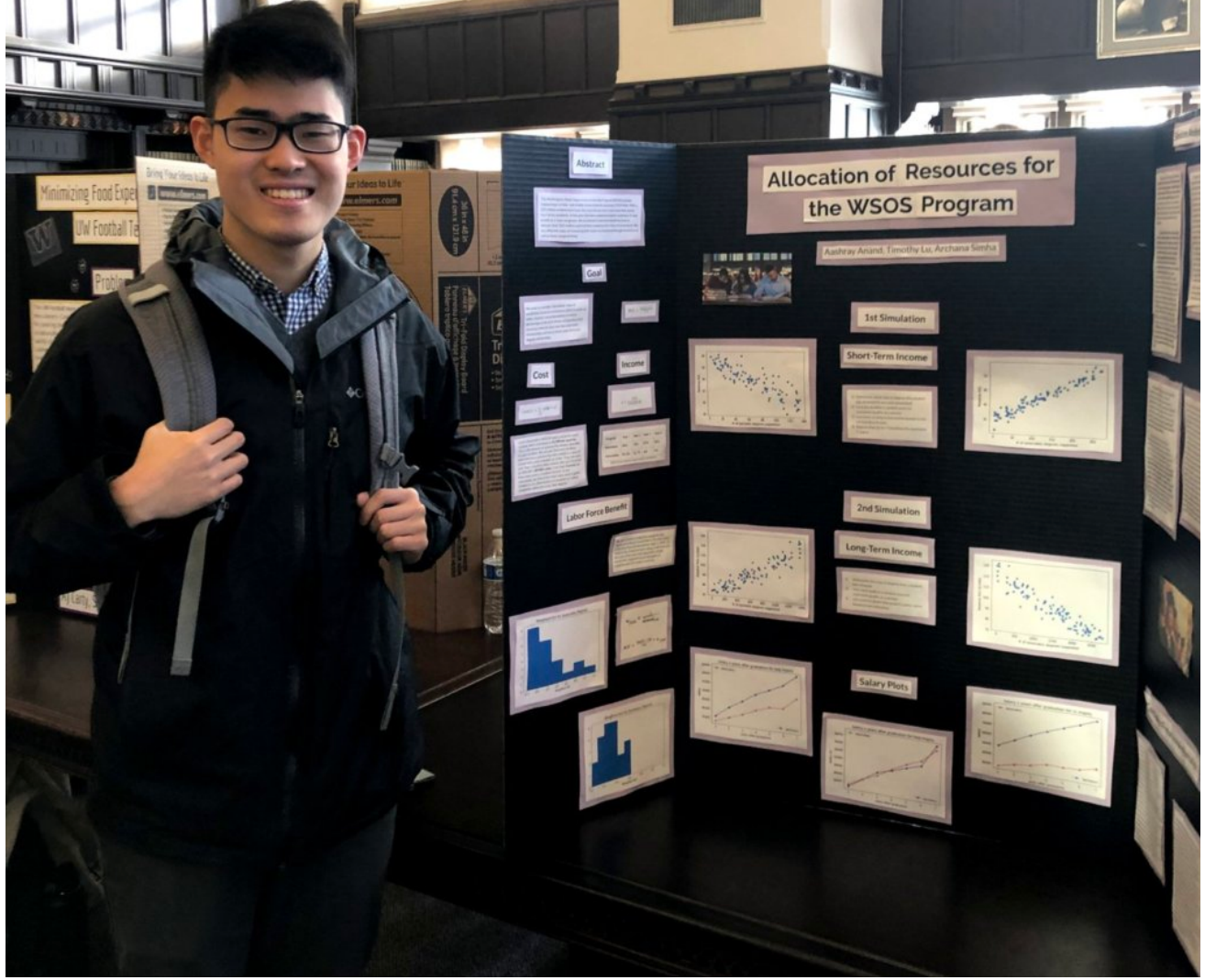
Improving Community in Local Churches



Team: John Beck, Elmira Mukambayeva, Kunjal Patel

How can we set the price of the upcoming young adult retreat so that we get the maximum participation given constraints of lodging, transportation, quality of experience, and food? Answer: use simulations!

Washington State Opportunity Scholarship Program



Team: Timothy Lu, Aashray Anand, and Archana Simha

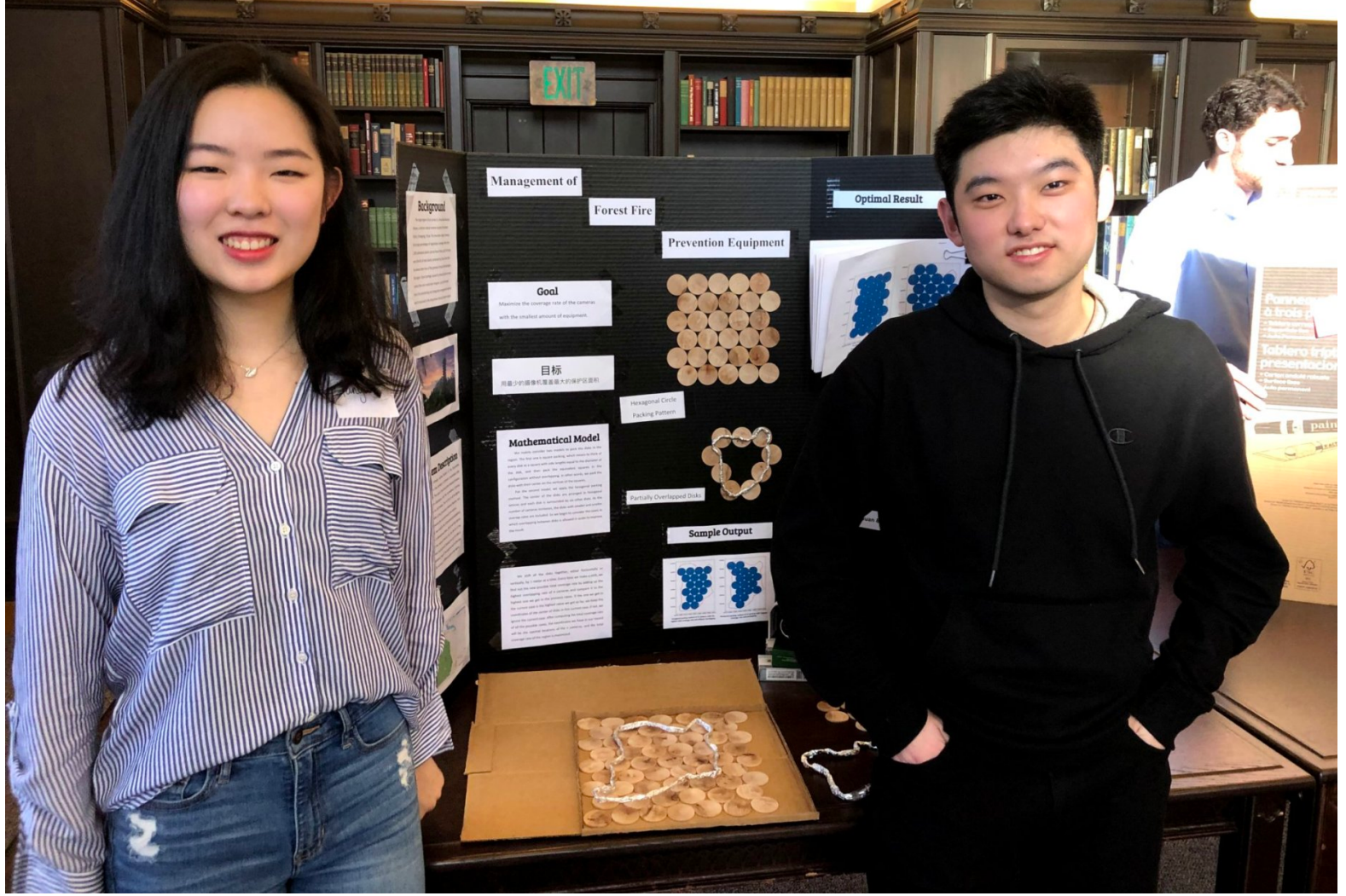
How can we most effectively allocate $25,000,000 in scholarship funding between 2 and 4 year colleges? Answer: use probability and statistics!

Improving free tax service offered by United Way

Team: Melissa Stadt , Irena Chen, and Jessica Fay

How can we most efficiently serve low income and elderly people coming to the library for tax preparation service given a two phase system including an initial preparation and a quality review? Answer: Queueing Theory and Simulations!

Forest Fire Detection



Team: Yanyan Guan and Peicheng Wang

Where should we place cameras to detect forest fires in Jinyunshan National Reserve in order to maximize the chance of detecting fire early while minimizing cost? Answer: Discrete Geometry!

Assessment and Outcomes

- 109 Community Related Projects done.
- Math was enthusiastically discussed with a diverse audience.
- Adding a Service-Learning component moved the entire class up.
- 284 Students (only 1 failed to submit a final project).
- Students take ownership of their projects, especially when they are using their own contacts.
- Students report this class was a huge benefit in getting their first job or motivating them to go to grad school in operations research, data science, education, math, stats, etc.
- "Creative Capacity Building" via mathematical maturity.

Assessment and Outcomes

Dear Professor Billey,

Thanks for writing the email reaching out to me! Yes, absolutely! I am totally okay with that.

I am currently within a master program studying Business Analytics at UCLA. I have to say that the content I learned from MATH381 was super helpful. The optimization class I am taking now is also teaching us how to use Gurobi in Python. Also, I guess I will never forget these two papers (volleyball tournament scheduling and boarding strategy). Every time getting on boarded, I will think about this paper :) And the experience working with a non-profit organization (final project) was actually my first time using math knowledge to help people around solving real problems in the real world. Because I personally received a lot of helps from this non-profit org when I came to the U.S., it is also kind of my way to give back to the community (even though our project found out they were already doing a great job on pricing). But it is still a very memorable experience for me.

At the end, hope everything will go well for your talk!

Best regards,
Jiarun Zhang

Why don't all math classes have a community component?

- Many real problems are hard to solve and hard to model.
- Some problems require creative new mathematical techniques.
- We don't encourage enough "trial and error" or the "risk of failure" in the classroom setting .. unless the teacher chooses to include it.

- **We need you to bring math to your community!**

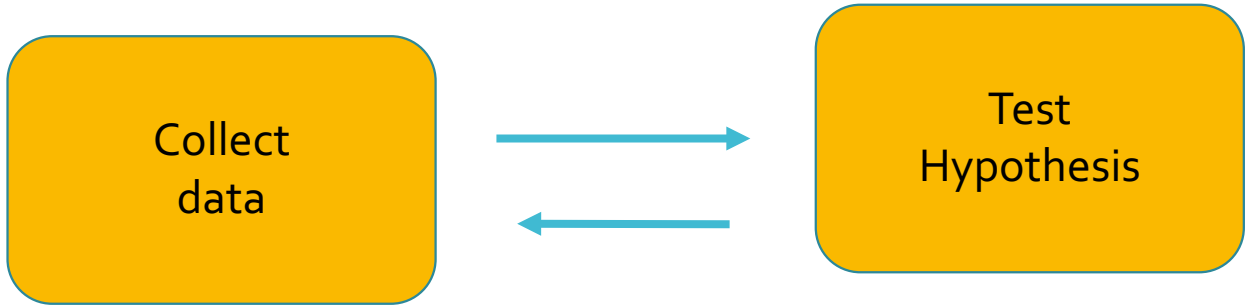
Structuring the process

- Important Dates: starting 9/26/2018:

Date	
Monday, October 15	Quiz 1
Monday, October 22	Project Proposals due
Wednesday, October 31	Revised Project Proposal due
Wednesday, November 7	Quiz 2
Friday, November 16	First draft of course project due.
Friday, November 30	Mandatory attendance: Peer presentations.
Monday, December 3	Mandatory attendance: Peer review.
Wednesday, December 5	Mandatory attendance: Poster session.
Tuesday, December 11	Final copy of course project due by 4:00pm. Deliver 2 copies of your project to Professor Billey's office (PDL C-445).

Get students talking on the first day!

Play 20+ questions game with a logic puzzle. Answers limited to yes, no, or irrelevant.



Identifying good projects

- Discuss examples in class.
- Assignment #1: Look around in your daily life for problems where discrete math may be used. Describe 3.
- Review the best ideas from Assignment #1 with the class and point to potential community partners.
- Ask: who else want to join these projects?
- Where else can we find community based projects?
  - Clubs
  - Jobs
  - Student Services
  - Friends
  - Family

Encourage students to talk to people about their "decision problems."

Write up a "one-pager" about the class for community partners.

Practice interviewing and listening

- Record an interview with a community partner who is wrestling with a decision problem.
- Listen carefully, take notes, what are the tradeoffs that make this problem hard to solve immediately.
- Write down a “one-sentence description of the goal” of the problem and desired format of the solution.
- Be gracious and respectful of their time.
- Job training for mathematicians.

Project Proposals

- Students write up 1-2 pages describing the community partner and their decision problem.
- Evaluate the proposals for clarity, feasibility, and make sure they have access to good data.
- Brainstorming session with Instructor and Students. Takes about 30 minutes per team. Best way to get to know your students, their problem, and to model mathematical conversation. Attack the problem with them at first.
- Students leave with a crystal clear one-sentence description of the goal which they need to confirm with their community partner.

Describing success: one beautiful sentence

- Writing down a clear description of the problem that needs to be solved and what are the deliverables is the key step for the proposal stage. Refining the goal into one clear sentence is the first step toward creating the mathematical model.

- **Examples:**

- "We want to provide multiple strategies to predict the return on investment (ROI) in order to make a holistic recommendation of which percentage of the $25 million scholarship fund should go towards four year baccalaureate scholarships and two to three year technical degree scholarships."

- "Our goal is to provide a detailed allocation plan consists of different levels of coverage rates of the desired region using the minimum amount of equipment."

Computational Resources

- **Fact**: You can solve much bigger, more interesting problems with computers than you can without computers.

- Which language to teach? Your choice! I have used
  - Python/Gurobi
  - Sage/Cocalc
  - R
  - Maple

Mathematical Resources

- Lectures, Wikipedia, Textbook, other faculty.

- Read articles and discuss in class:

- Inventory Decisions in Dell's Supply Chain (Interfaces, 2004)
- America West Airlines Develops Efficient Boarding Strategies (2005)
- Scheduling the Italian National Volleyball Tournament (2018)
- Increasing Efficiency for United Way's Free Tax Campaign (SIURO, 2018)

First Draft

- The first drafts range from barely started to almost finished. The quality of solutions and writing varies. References may not be included. Assumptions may not be well justified. They may make false statement.
- Instructor feedback is critical at this point. Stay positive. Give compliments first before launching into the suggested improvements.
- Suggest a visit to the writing center if grammar and logical flow are below average. The projects need to be understandable to a broad audience including community partners and other students in the class.

Peer-to-Peer presentations

- In order to be sure that your model/solutions are solid, you have hired an an auditing firm for $1000 / day to review your work. They are a group of bright mathematicians like yourself but they have not thought about this specific problem before. Explain your key decision question, the model you propose and your solution to them carefully but briefly (so they don't charge you overtime.) You will want to explain enough to them that they will be able to understand EVERYTHING in your write-up easily. Focus on the hard parts.

Peer-to-Peer presentations

- For the presentations:
- Bring a copy of your written draft for each reviewer.
- Prepare a 15-20 minute presentation. Be willing and flexible enough to take questions as you go through the presentation. The more they ask, the more they can help you.
- You must be there on time and plan to stay for the entire class period.

Peer-to-Peer presentations

Among the most important skills required for modeling is being good at evaluating models. Sometimes it is easier to critique other people's work than it is your own, but it is the same skill. Your mission is to help the opposing modeling team to identify gaps in their reasoning, suggest improvements in their model, improve their writing for the intended audience and insure they are getting their key points of persuasion across.

During the process keep in mind the following:

Auditors motto: If the auditor doesn't understand it, then it is either false or it is too obscure for the intended audience to ever understand it. It must be fixed.

Peer-to-Peer presentations

During the modeling presentations:

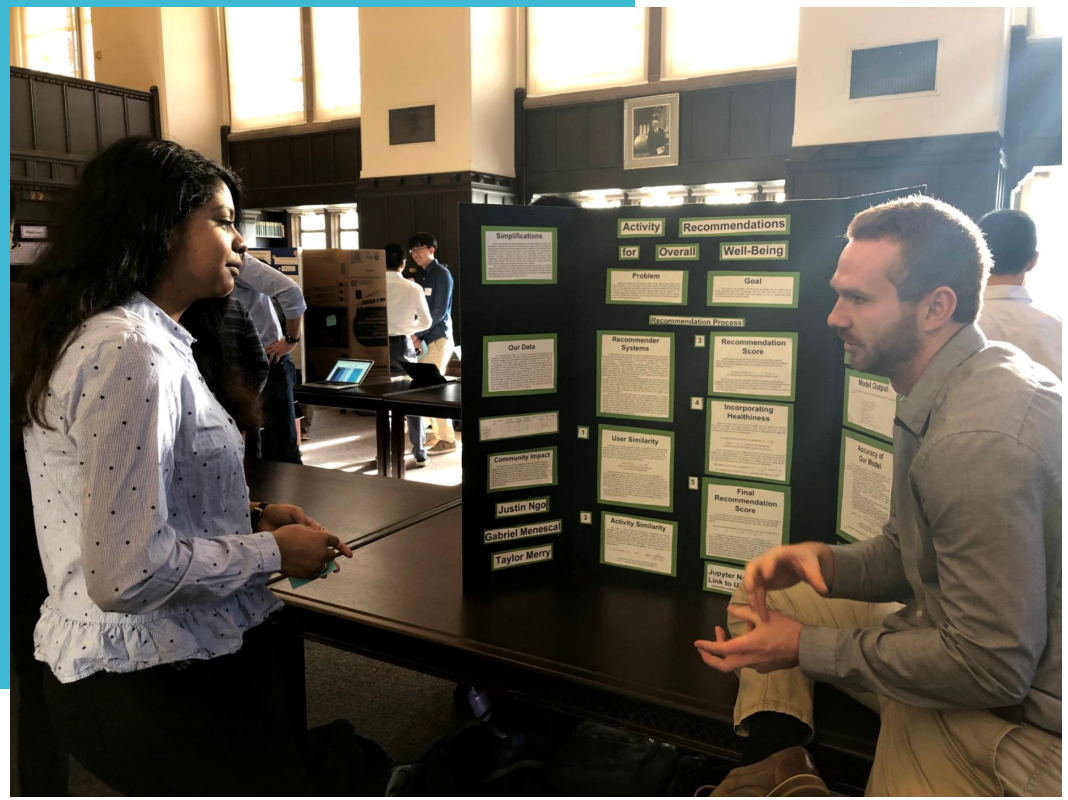
Listen carefully and take notes on difficult points.
Ask questions whenever something isn't clear. Questions will help them know what is easy and what is hard to understand.

For the review presentation:
Read their paper. Be sure to note the parts that were persuasive and/or unclear. You can mark a whole paragraph if you are confused. Identify typos, particularly in the math. Verify math statements are all justified by an argument or a reference. Verify they have given the correct answer to the key question(s) in the conclusion.

Each auditor should prepare a written review about 1 full page long summarizing your compliments and suggestions.
Present your compliments and suggestions orally in 5-7-minutes.

Poster Session

- **A Celebration of 10 weeks of hard work!**



Students get to present their work to many different people, with different mathematical backgrounds, different interests, and get awesome feedback!

Community partners come and find inspiration for future projects.

Students come and learn how their course work is being applied.

Faculty and grad students come and support the undergrads.

Harness the power of a public witness! Final projects are much, much better because of these conversations.

Other Resources

Cosmo Wang

- “Math 381:Discrete Math Modeling”
- https://sites.math.washington.edu/~billey/classes/math.381.fall.2018/
- ”**Interfaces**” articles. Now called “***INFORMS Journal on Applied Analytics***”
- “**Operations Research**” by Wayne Winston. (any edition)
- ”Mathematics in Service to the Community: Concepts and Models for Service-learning in the Mathematical Sciences” (Maa Notes #66) edited by Charles R. Hadlock.
- The service-learning office on your campus.
- Libraries.

Many Thanks !