Math in the City
The Nuts and Bolts of a Hands-on Learning Experience

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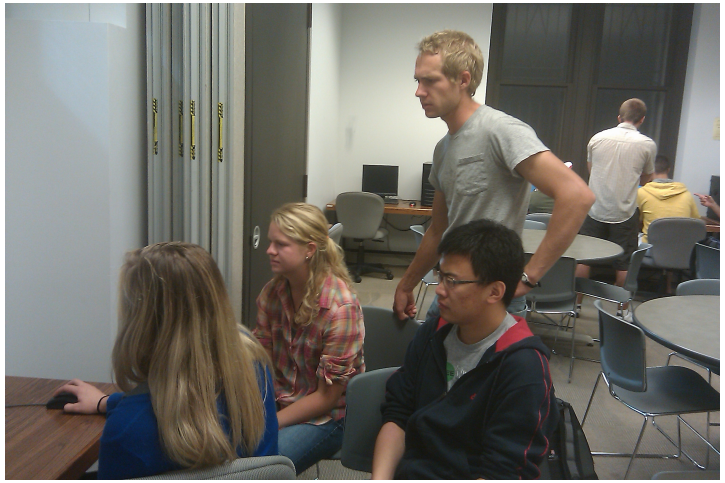

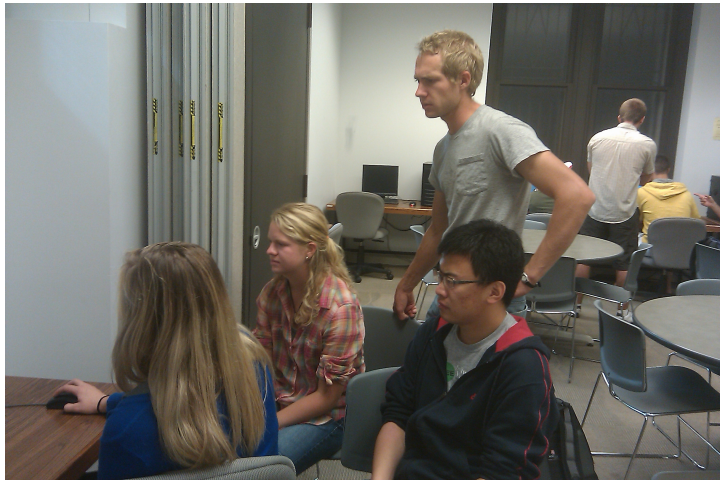

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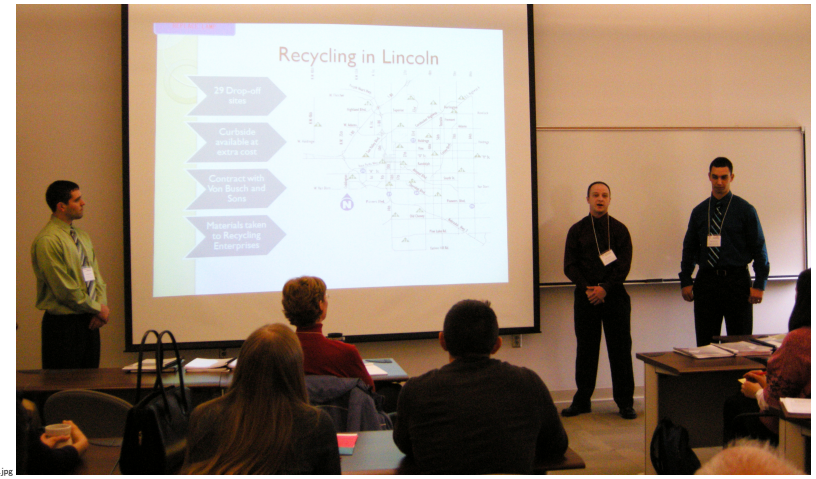


Course Timeline

Before classes start:

- talk to people in the Department about offering the course (best time to offer it to increase enrollment)
- start recruiting students: put posters up, send emails to students and student advisors, announce course to classes
- think about suitable projects; what mathematical background?
- contact potential collaborators
- Fall 2010: projects involving routing
  - Post Office, grocery stores
  - Union Pacific railroad
  - recycling companies, city of Lincoln

Establishing the Collaboration

- Meetings with collaborators
  - What data can they provide?
  - What are questions they would like answered?
  - What are reasonable things that can be done during the semester?
- see sample of the data and sketch a road map for the project
- prepare a set of lecture notes that contain the necessary material for the project

Project Timeline

After classes start:

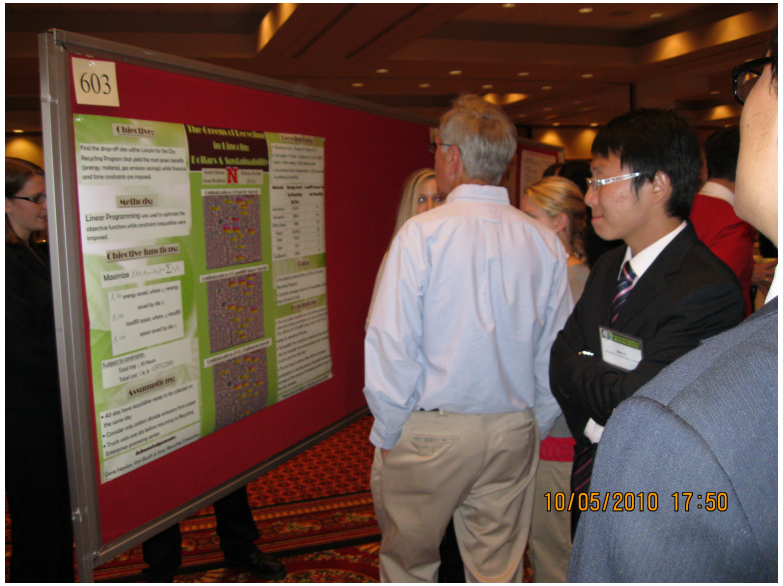
Project Phase I (weeks 1–5)

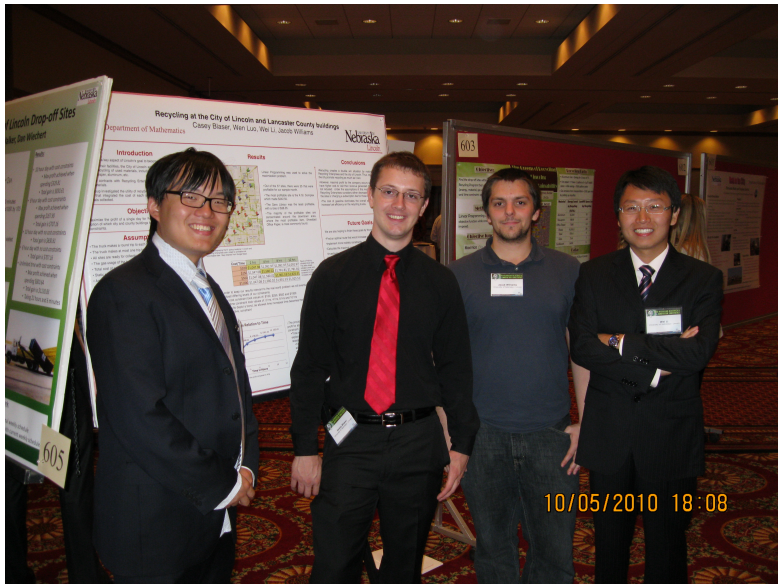
- introduce students to project; presentation by collaborator
- form groups
  - projects can have different data, but similar questions
- students examine provided data and gather additional data from other sources
  - data is given lots of formats and measurements
  - data overload
- students research and write about a topic related to the project; each student becomes an expert on one topic relevant to the course
- discussion of mathematical modeling (introductory concepts that allow students to think outside the box) and background material that will be necessary for the work on the project (presented at the level that will be needed)

Mid-Semester Goal

- "test run" of the end-of-semester pulling things together
- by this point, students have some good understanding of problem, data, and their project goal; have preliminary results
- can be a checkpoint during the semester
- example: Nebraska Research and Innovation Conference
  - sponsored by Nebraska EPSCoR
  - to foster industry, govt, and academia connections
  - students presented at the poster session
- wrote a report of these results, including introduction and motivation; start of final report
- benefits of presenting results outside the class; student reaction; DD

Posters at Nebraska Research and Innovation Conf. on Oct 5, 2010





Project Phase II (weeks 6–12)

- the mathematical content has already been covered, students are ready to use the tools on the data provided
- work in groups; whole class discussions are limited only to topics that concern all groups
- mathematical models created: set up of variables, equations, find restrictions for the variables and the parameters; discuss existence of solutions
- models implemented as computer programs
- Repeat process:

  model solved $\Rightarrow$ results interpreted $\Rightarrow$ refine model

  until satisfactory result achieved
- students start writing their results

Project Conclusion (weeks 13–16)

- students reconsider assumptions, create more realistic model
- during this final period there is a lot of brainstorming going on: students fully understand the problem and try different ways to come up with an optimal solution; they need guidance to channel their ideas, otherwise they start feeling overwhelmed by the scope of the problem
- compile results, give conclusions, and offer recommendations
- write final report as an iterative process of students sending drafts and instructors providing comments.
- prepare slides, give mock presentations in front of the classmates; give final hour-long presentation for each group in front of a large audience

Ingredients for Projects: Course Material

- adjusted each semester to better fit the projects
- different topics, but the material is self contained
- sets of 8–10 self-contained lectures in Mathematical Modeling, Statistics, Differential Equations, Linear Algebra, Linear and Integer Programming, Traffic Models, Routing Methods, and Math Programming
- no textbook, but students are encouraged to read the references given to them, relevant to the topic (information on the web, information provided by the collaborator, handouts and textbooks for mathematical content)
- Computer programming: Excel, SPSS, Maple, Sage

Managing Groups

- having student buy-in from everyone is key
- expectations need to be clearly set, and instructor needs to step in when necessary
- discussions with each group during each class meeting time
- as the end of the project got closer, students needed to meet more outside of class as a group
- had students keep journals where they recorded their work, plus what they were confused about or future directions
  - I learned that ...
  - I had difficulties with ...
  - I need to do ...
- experience with group work from other classes, disciplines
- possibility of having group leaders?

Sample Journal

Mon Aug 30, 2010

Today Gene Hanlon (in charge of recycling for the city of Lincoln) came and talked to our class about recycling in the city. He clarified a lot of questions I had looming in my head about how the process of recycling works in the city.

- I learned a lot about recycling in Lincoln including a lot of monetary aspects I hadn't previously known. I feel that his powerpoint handouts will be very useful throughout this semester.
- I need to skim through the slides again to see what (if any) data is directly related to the green project.
- Once again, all of this data made me feel a bit overwhelmed and I really need to sit down and figure out what steps need to be taken, I feel like I am already behind and we haven't really even started much work on our projects. Is everyone else feeling this way?

Assessment of student work

- most of the work is done in groups, how should individuals be assessed?
- the grade is a linear measure to assess nonlinear performance; what is more important: mathematical analysis or interpretation/communication of results?
- most of the credit is assigned to work on the project, but the grade for the final report provides only a portion of the grade; other components: participation during the semester (weekly updates and student journals), individual presentations, homework assignments

Assessment

Example Grade Breakdown:

20% Homeworks

30% Project participation (documented through student journals, communication with team and instructors, participation in the poster session)

35% Project (memos, intermediate drafts, final report)

15% Performance during oral presentation (understanding of the work, communication skills, quality of the slides)

Challenges

From the instructor's point of view:

- finding a good project:
  1. what type of math problems would be suitable?
  2. what businesses to approach? what data is available?
- instructor needs to be able to adjust (at any time) the course of the project in case the data is insufficient or incompatible with the mathematical tools available; handle the case when no optimal solution can be found
- motivate students and keep them focused when a roadblock appears, or when they feel overwhelmed (especially during initial and final stages)

Challenges

- different backgrounds for the students
- scheduling time for lectures and meetings; possible approaches: work with each group for 15-20 minutes every lecture, or meet with every group once a week for a full hour.
- management of group work; need involvement of all students
- assess individual work

Challenges

From the student's point of view:

- tackling an open-ended problem where the approach is not clear (even to the instructors!)
- learning non-mathematical background necessary for the project
- need to effectively communicate with peers, instructors, and collaborators, both quantitatively and qualitatively
- teamwork is necessary; students depend on each other to complete their work, so they have to trust their teammates with the work that is being done (and graded)
- conflicts in their schedules (they have to meet to do the work)
- need to research mathematical and non-mathematical issues without a textbook

Benefits to the Students

Educational:

- students understand how to translate a complex real-life situation into a mathematical model
- develop better communication skills in writing and for oral presentations
  - hour-long presentation to wide audience during the last week of classes
  - written report
  - possible poster presentations (Nebraska Research Expo, UNL Undergraduate Research Fair)
- learn mathematical software: SPSS, SAS, Maple, Sage
- exposure to workplaces outside academia (they can show off and improve their "employable skills")

Benefits to the Students

Personal:

- learn how to deal with setbacks, meeting deadlines for their project, how to work in groups, learn to take initiative
- increased self confidence and sense of achievement
- connect with possible employers in the city; find job or internship opportunities
- the course provides a non-standard experience that students will remember and tell to others (interviews)

Student Feedback

- "How to value different raw data is one of the most important skills I learned. I also gained some skills to pick and choose goals that are reachable from goals that cannot be finished."
- "No specific answer to the problems. Instead of like a normal textbook, you just open up the back to see if you got it right, in this course you have to decide if you think it is right or not."
- "Liked using raw data to find what was useful in it to solve the problem"
- "Experience working with a group on a much larger project than what could be done by an individual. "
- "It made you think. A lot."

Student Feedback

The students were challenged to work on difficult problems, but they enjoyed testing and developing their abilities:

- "I also liked the fact that we didn't know what we were capable of doing until we did it."
- "Enjoyed a trial and error approach to problem solving by trying a method see if it would work and then trying another method if it didn't."

Students also commented that they felt more involved in the Mathematics Department than with other classes (especially through their participation in the poster session).