LEAN OUT
Connecting Outside the Ivory Tower

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Mathematical Scientists in Industry

AMS Report on New Doctoral Recipients

http://www.ams.org/profession/data/annual-survey/survey-reports

Year PhD completed	# of new PhDs employed in US – first job	# or new PhDs employed in US BIG	% of new PhDs employed in US BIG
2007-2008	1026	270	26.3%
2008-2009	1166	305	26.2%
2009-2010	1163	292	25.1%
2010-2011	1191	316	26.5%
2011-2012	1300	406	31.2%
2013-2014	1412	486	34.4%

~40% of new PhDs in Stats/Biostats go into non-academic jobs

Mathematicians in Industry

AMS Report on New Doctoral Recipients

http://www.ams.org/profession/data/annual-survey/survey-reports

Year PhD completed	# of new PhDs employed in US – first job	# or new PhDs employed in US BIG	% of new PhDs employed in US BIG
2007-2008	730	135	18.5%
2008-2009	795	144	18.1%
2009-2010	767	139	18.1%
2010-2011	825	158	19.2%
2011-2012	846	213	25.2%
2013-2014	926	243	26.2%

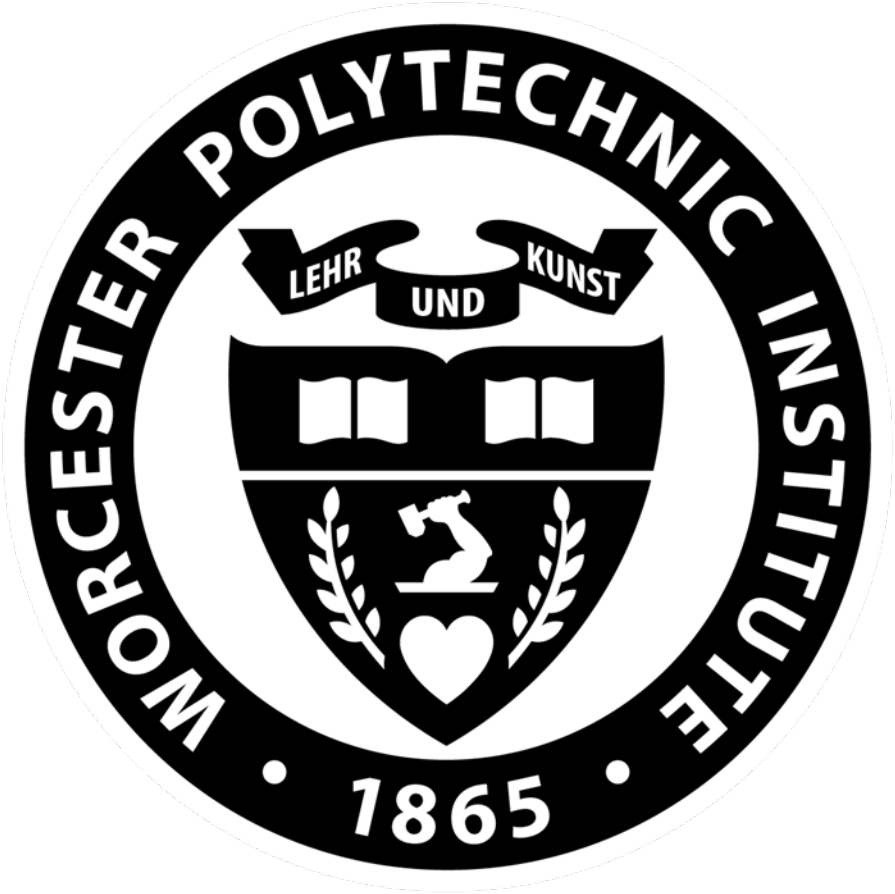
It Behooves Us to Know

- What is the role of a mathematician in business and industry?
- What is it like to work with technical experts on a problem that requires significant mathematics but also must satisfy real-world constraints?
- What kind of mathematical and statistical tools are used to solve problems in business and industry?
- What skills are important to be successful?
- What can we do to better prepare our students?

CIMS
Center for Industrial Mathematics and Statistics

WPI

Theory and Practice



The WPI Plan

Projects are central to the WPI Plan

Undergraduates must complete:

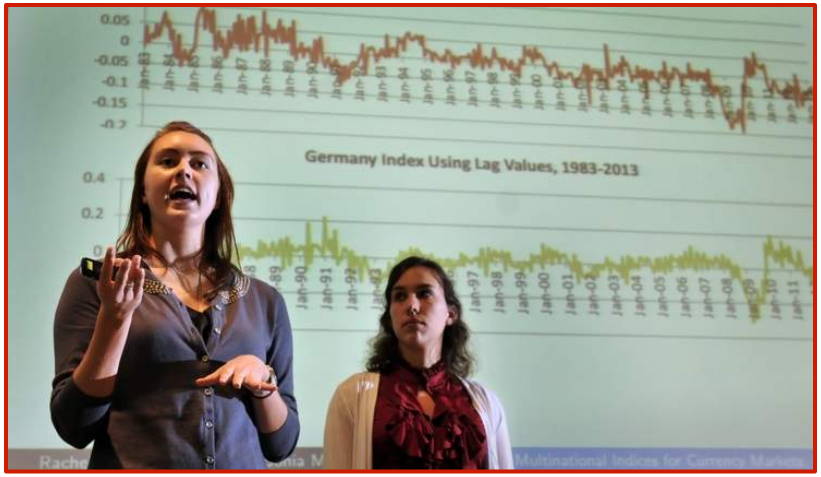
- Humanities and Arts Requirement
- Interactive Qualifying Project (IQP)
- Major Qualifying Project (MQP)

Major Qualifying Projects at WPI

All WPI undergrads must do original research in their major area.

GOALS:

- formulate a problem, develop a solution and implement it competently and professionally,
- demonstrate application of the skills, methods, and knowledge of the discipline,
- work in teams and communicate well, both orally and in writing.



WPI

Benefits of Undergraduate Research

Increased success in

- ✓ problem solving
- ✓ critical thinking
- ✓ independent thinking
- ✓ creativity
- ✓ intellectual curiosity
- ✓ disciplinary excitement
- ✓ communication skills

WPI

Motivating Students

Some students are attracted to the

intrinsic beauty of mathematics.

Others need to see the **direct impact** of their work and its relevance to societal need.

WPI

Industrial Math at WPI

Center for Industrial Mathematics & Statistics

- Founded in 1997
- Make partnerships with industry that benefit the sponsors, and WPI's mathematical sciences community
- Real-world research projects that come directly from industry, government and finance

Visit http://www.wpi.edu/+CIMS

Benefits to University

- Students gain real-world experience that makes them more competitive in the job market
- Real-life problem-solving
- Professional development in a professional setting
- Development of communication skills crucial for the workplace
- Summer and post-graduate employment opportunities
- The faculty gain valuable experience that enriches their teaching and research.

Benefits to Industry

CIMS helps companies address their needs for mathematical solutions and enhance their technological competitiveness

- Access to expertise of faculty members who can help identify and solve critical problems
- Access to bright, energetic students
- Access to the latest scientific research developments
- Access to state-of-the-art computing facilities
- Active participation in the educational process
- Opportunity to identify and help train potential future employees

CIMS Partners

130+ projects

75+ companies

GenomeQuest

DRAPER LABORATORY

SATMAP™

TRAVELERS

John Hancock

DEKA

SRI International

unum

Advanced Sports Logic

Chitika

Sun Life Financial

BOSE

AdHarmonics

WPI REU Program in Industrial Math and Statistics

DMS9732338, DMS0097469, DMS0353816, DMS0649127, DMS1004795, DMS1263127

1998 – 2015

- *18 summers*
- *56 projects*
- *28 companies*
- *198 students*
- 141 colleges
- 45 regions

Visit http://www.wpi.edu/+CIMS/REU

REU Advisors

- Art Heinricher
- Bogdan Vernescu
- Marcel Blais
- Burt Tilley
- Matthew Willyard
- Jon Abraham
- Bill Farr
- Roger Lui
- Andrew Swift
- Bogdan Doytchinov
- Minghao Wu Rostami
- Ann Wiedie
- Jayson Wilbur
- Vadim Yakovlev
- Zheyang Wu
- Carlos Morales
- Christopher Larsen
- SLW

WPI

Getting the Job Done

Understand the problem and the needs of the sponsor

Get to work

Communicate the approach, results, & conclusions

Four Key Features

- Industrial math projects have impact …

  Math is used to make a real decisions.

- There is rarely one right answer …

  But there are good solutions and bad solutions.

- Formulating may be as hard as solving …

  The problem is not given at the end of the chapter.

- Communication is crucial …

  If you cannot explain it, your solution is worthless.

Lessons Learned in Project Work

- Define a clear goal

  over and over again…

  … it may change

  *… it **will** change!*

- Communication is crucial

  Learn to ask questions…

  …until you get it!

- You must take a stand

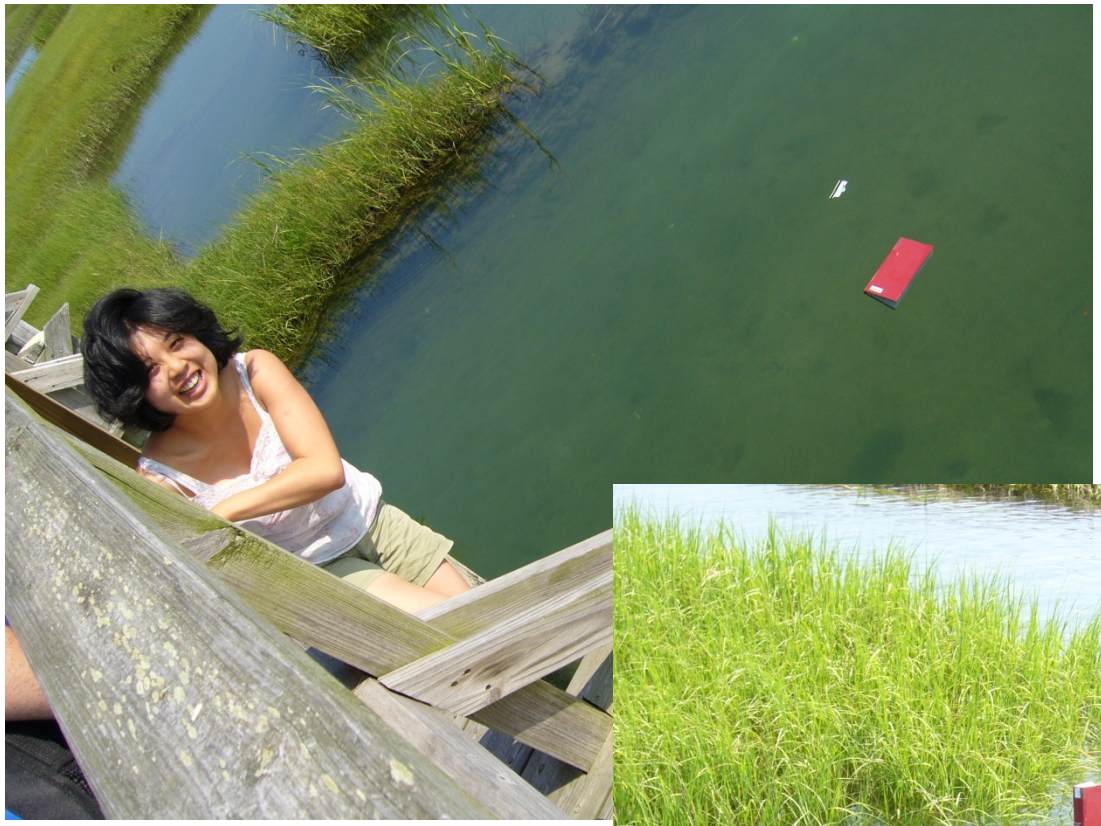
  and support your conclusions…

  …in writing!

Skills Needed

- ✓ Programming
- ✓ Statistics
- ✓ Probability
- ✓ Differential Equations
- ✓ Linear Algebra
- ✓ Modeling
- ✓ Numerical Simulation
- ✓ Operations Research

- ✓ Communication skills
- ✓ Ability to work effectively in a team
- ✓ Enthusiasm
- ✓ Self-direction
- ✓ Ability to complete projects



& tenacity!

RESEARCH EXAMPLES

Draper Labs Project MQP 2014/2015

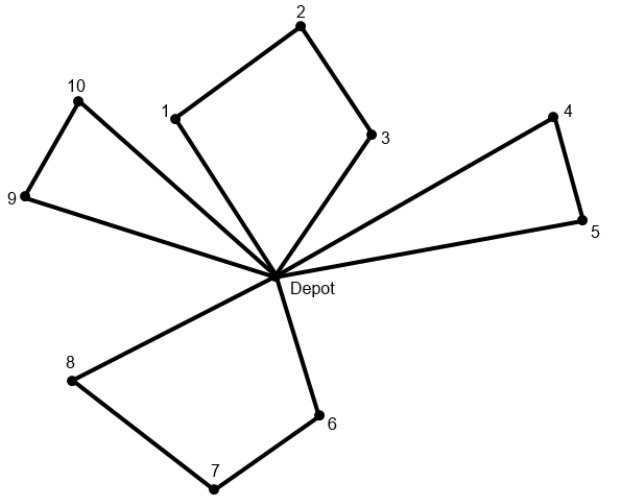
Charles Stark Draper Laboratory – Cambridge, MA

- Non-profit research and development laboratory
- Specializes in navigation, guidance, and control systems
- Working with NASA to improve the efficacy of missions to observe Earth phenomena

Pre-Mission Flight Planning

Students: Alexander Sunde-Brown, Ethan Moon

Develop a pre-mission flight plan for UAVs to gather data from a set of sites over several days



DRAPER LABORATORY

Industry CIMS WPI

Model Formulation

$$\text{minimize} \quad \sum_{i,j \in G} c_{i,j} x_{i,j}$$

$$\text{subject to} \quad \sum_{i \in N} x_{i,j} + \sum_{i \in N} x_{j,i} = 2 \quad \forall j \in N,$$

$$\sum_{j \in N} x_{0,j} = 2k$$

$$\sum_{i \in S, j \in G \setminus S} x_{i,j} + \sum_{i \in G \setminus S, j \in S} x_{i,j} \geq 2 \quad \forall \text{ tours } S \; s.t. \; |S| \geq 1$$

$$\sum_{i=2}^{d-1} x_{a_i,a_{i+1}} + \lambda x_{a_1,a_2} + \lambda x_{a_d,a_{d+1}} \leq |Q| + \lambda - 2$$

$$\forall \text{ depot tours } Q \; s.t. \sum_{j=1}^{d} c_{a_j,a_{j+1}} + \sum_{l=1}^{d} w_{a_l} > M, |Q| \geq 3$$

$$x_{i,j} \in \{0,1\} \qquad \forall i,j \in N$$

$$x_{0,j} \in \{0,1,2\} \qquad \forall j \in N$$

Silverlink Communications REU 2014

Silverlink Communications – Burlington, MA

- Silverlink Communications delivers multi-channel communications campaigns designed to motivate better health decisions.

- Silverlink consults for insurance companies to implement cost-effective communication methods
  - Example: phone call reminder for colorectal cancer screening

Predictive Power of a Generalized Preventive Care Segmentation Model

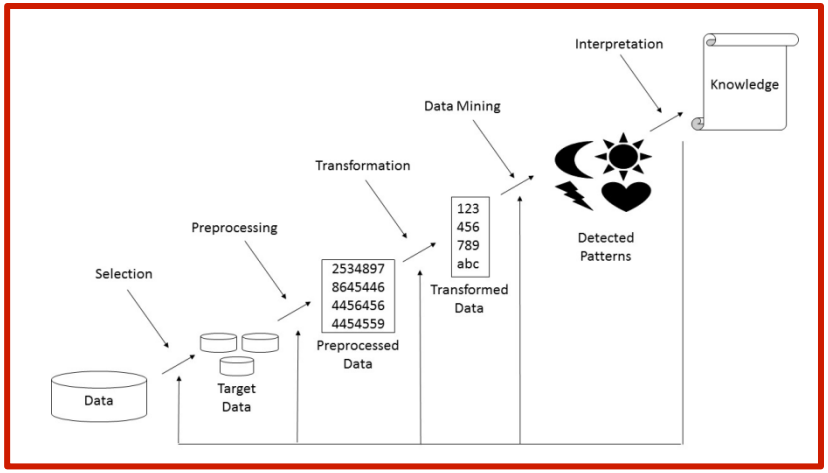
Students: Ciaran Evans, Parker Hund, Eric Varley, Devin Wang

Advisor: Dr. Matthew Willyard (WPI REU 2002)

- Create a model that segments an insurance company's customers into groups based on their likelihood to obtain preventive healthcare
- Silverlink will use the model to determine with whom they will communicate
  - By only communicating with customers who are likely to respond, communication costs are lowered
- Only have access to claims data

Silverlink

Data Mining



- Knowledge Discovery in Databases process
- Conglomeration of statistics, computing, and machine learning techniques for detecting patterns in and finding information from large quantities of data

	Linear Regression		CART		CART Forest		cTree		CForest	
	R^2	Risk	R^2	Risk	R^2	Risk	R^2	Risk	R^2	Risk
Future Actions	0.302	2.109	0.296	2.132	0.291	2.146	0.302	2.113	**0.308**	**2.094**
Future Visits	0.322	0.759	0.318	0.766	0.312	0.773	0.317	0.766	**0.331**	**0.751**

	Logistic Regression	Naive Bayes	CART	CART Forest	cTree	cForest	CHAID
AUC	0.814	0.788	0.800	0.808	0.812	0.814	**0.813**
Acc.	**0.741**	0.720	0.736	0.733	0.740	0.738	0.735

THE PIC MATH PROGRAM

The PIC Math Program

Preparation for **I**ndustrial **C**areers in **Math**ematical Sciences prepares mathematical sciences students for industrial careers by engaging them in research problems that come directly from industry.

http://www.maa.org/pic-math

Michael Dorff, Brigham Young University & SLWeekes

DMS 1345499

MAA 100 CELEBRATING A CENTURY OF ADVANCING MATHEMATICS
MATHEMATICAL ASSOCIATION OF AMERICA

PICMath

PIC Math Program Goals

- Increase awareness among math and statistics faculty and undergraduates about non-academic career options
- Provide research experience working on **real-world problems from business, industry and government**
- Prepare students for industrial careers.

http://www.maa.org/pic-math

PICMath

PIC Math Faculty Summer Workshop

- Information on non-academic careers
- Guidance on developing business and industry connections
- Exposure to mathematical and statistical problems that arise in business and industry
- Training on how to develop skills in students that are valued by employers.

PICMath

http://www.maa.org/pic-math

Spring Semester Research Course

- PIC Math faculty run a spring semester, credit-bearing course on solving industrial problems
- Information about industrial careers
- Training for industrial careers
- PIC Math provides material, financial, and emotional support material for the course

PICMath

Student Research Competition

- PIC Math faculty mentor a “PIC Math team” of students at their college to work on an industrial problem.
- Students submit a recorded oral presentation and written report of their solution.
- A panel of judges will give feedback and an assessment of each team’s submission.
- Students present their results in person at a summer conference at the MAA MathFest or SIAM meeting.

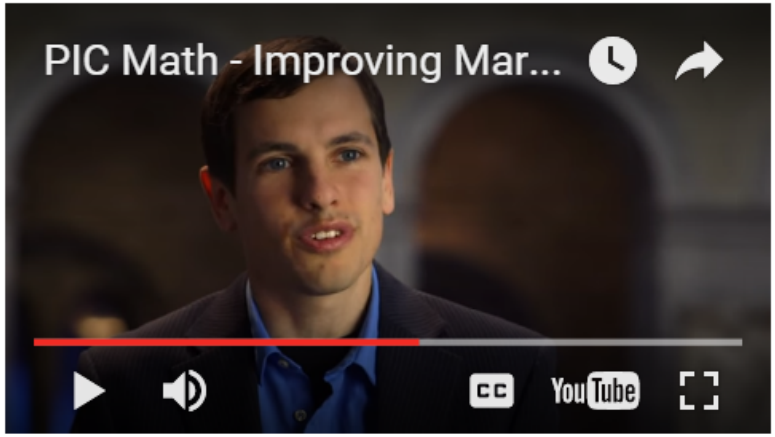
siam®

MAA 100 MATHEMATICAL ASSOCIATION OF AMERICA CELEBRATING A CENTURY OF ADVANCING MATHEMATICS

PICMath

Industrial Case Studies Videos

We produced four **2-video sequences** highlighting some research problems that mathematicians and statisticians encounter outside of academia.



Go to **Industrial Math Case Studies** at http://www.maa.org/picmath

PICMath

Industrial Case Studies Videos

The first video features a professional mathematical scientist talking about their career and some of their research.

The second video features a faculty member presenting an approach, with technical details, that one may use to make progress on the industrial research problem.

PICMath

The Videos

PICMath

Improving Marketing Strategies

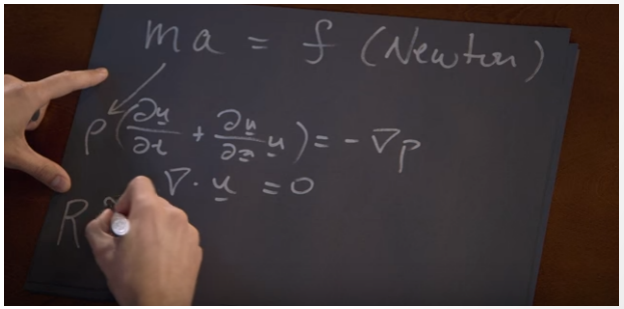
Use text analytics to help an online company distinguish between its business customers and its private consumers from messages on gift cards.

Dr. Jonathan Adler **Prof. Talithia Williams,** Harvey Mudd College

Creating More Realistic Animation for Movies

Use mathematics to make realistic, art-directable animations to simulate phenomena such as water, fire, smoke, wind in the movie and gaming industries.

Dr. Alex McAdams, Disney Animation Studios **Prof. Joseph Teran,** UCLA



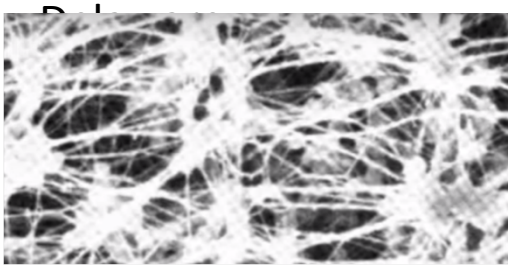
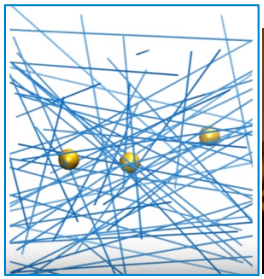
The Videos

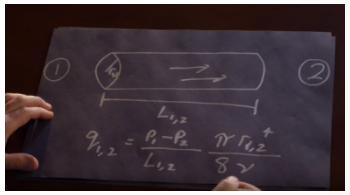
PICMath

Building a Better Filter

Use mathematics and statistics to help understand waste capture mechanisms and to optimize microstructures to create better filtration devices.

Dr. Sumanth Swaminathan, W. L. Gore & Assoc. **Prof. Louis Rossi,** U. of

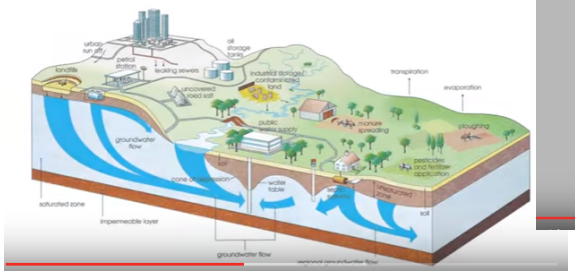
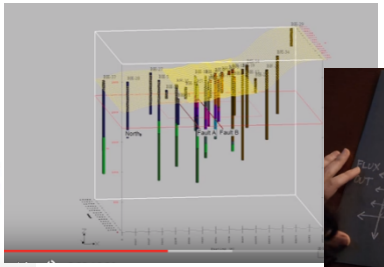
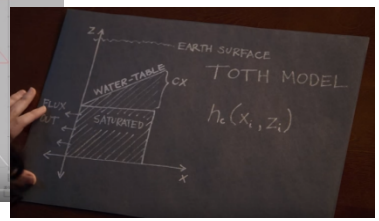



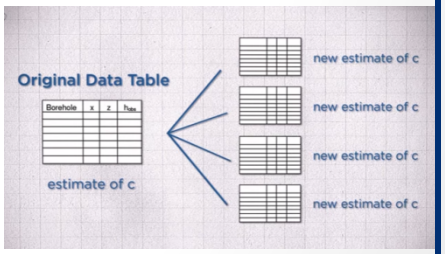


Finding the Safest Place to Store Nuclear Waste

Use mathematics and statistics to study the feasibility and safety of prospective subsurface nuclear waste storage sites using limited geologic data.

Dr. Genetha Gray, Intel **Prof. Gwen Spencer,** Smith



GRADUATE STUDENT MODELLING CAMP & MPI

Mathematical Problems in Industry

MPI is a 1 week problem solving workshop

engineers and scientists from industry work with

applied mathematicians and scientists from universities

to solve problems of interest to their companies.

2017 MPI @ New Jersey Institute of Technology, June 19-23

Grad Student Math Modeling Camp at WPI preceding MPI

..., WPI (2013), NJIT (2014), U. of Delaware (2015), Duke (2016)

..., DMS 1261594

Grad Student Math Modeling Camp

Worcester Polytechnic Institute June 2017

- Mathematical modeling and analysis
- Scientific computation
- Data analysis
- Interdisciplinary problems
- Industrial problems
- Graduate student teams
- Guidance by mentors
- Scientific communication

- Students attend the Mathematical Problems in Industry Workshop.

INDUSTRIAL MATH WITH TEACHERS

Toyota-RIT Math Initiative

For high school mathematics teachers interested in exploring:

- how the math and statistics taught in high school is used by professionals,
- what career paths are open to students well-trained in math,
- how high school math forms the foundation for college success.

Rochester Institute of Technology, Univ. of Delaware, Univ. of Minnesota

TOYOTA

WPI

Industry CIMS WPI

MIST

Applied and Industrial Mathematics Institute for Secondary Teachers

4 days 33 teachers 10 industry speakers

8 faculty speakers 1 robot 3 REU talks

+ homework

Industry CIMS WPI

Industrial Math Projects for High School Students

https://www.wpi.edu/+CIMS/IMPHSS/

- Developed with Research Experience for Teachers
- Directed by **Prof. Art Heinricher**
- 20+ industrial mathematics projects for high school students drawn from a variety of real-world situations.
- Projects for every level of high school mathematics, from Algebra to Calculus and Statistics
- Flexible length and scope of the projects
- Project database contains downloadable versions of each of the projects, ready to be assigned to students.

GE Foundation

NSF

Industry CIMS WPI

IMPHSS Projects List

- BioMass
- Ceramic Capacitors
- Ceramic Powder Manufacturing
- Child Mortality
- Criminal Intentions
- The Enigma Key
- Enter the iBot
- The Geometry of Investing
- The Illusion of Control
- Investment Banking
- ISD Certification Testing
- Listen to Periodic Functions
- Manufacturing Capacity
- Mining the MCAS - Algebra
- Mining the MCAS - Statistics
- Moral Hazard Test
- Network Analysis
- Network Damage
- The Question of Policy Loss
- Six Sigma for Algebra
- Six Sigma for Statistics
- SuperSoakers
- Taffy Production Line
- Vapor Recovery Systems
- Wearing Through the Pipe
- You're in the Driver's Seat

WPI

Industry CIMS WPI

Projects Aligned with NCTM Standards

Click here for a copy of the
NCTM Standards for Mathematics

	Suggested Classes	Number and Operations	Algebra	Geometry	Measurements	Data Analysis and Probability
BioMass *Research and assess alternative energy sources*	Modeling	12.N.9	12.A.6 12.A.14		12.M.1 12.M.5	
Ceramic Capacitors *Maximize yield and profit in a manufacturing process*	Pre-Alg Algebra 1 Geometry	8.N.1 8.N.4 8.N.7 8.N.11 8.N.14	8.A.2 8.A.4 8.A.6 8.A.7 12.A.9 12.A.12 12.A.14		8.M.2 8.M.3 8.M.8 8.M.9 12.M.1	
Ceramic Powder Manufacturing *Determine parameters for powder manufacturing*	Pre-Alg Algebra 1 Geometry	8.N.1 8.N.4 8.N.7 8.N.11 8.N.14	8.A.2 8.A.4 8.A.6 8.A.7 12.A.9 12.A.12 12.A.14		8.M.2 8.M.3 8.M.8 8.M.9 12.M.1	
Child Mortality *Study factors that effect life insurance cost*	Statistics Modeling	12.N.9	12.A.2 12.A.5 12.A.6 12.A.9 12.A.11 12.A.12 12.A.13		12.M.1	12.D.5
Criminal Intentions *Determine where in the 50 states it's safest to live*	General Algebra Statistics					8.D.2 8.D.3 8.D.4 12.D.4 12.D.5
DMAIC - Algebra *Analyze a company and recommend areas to improve*	Version 1 Pre-Al General Algebra	8.N.1 8.N.11				8.D.2 8.D.3 8.D.4 12.D.4 12.D.5
DMAIC - Statistics	Version 2					12.D.4 12.D.5

Industrial Mathematics Project for High School Students - Projects

Home | Projects | Standards | Tutorials | Sponsors | About | Contact

Click a project name for more information. Each project has an explanation and a classroom-ready downloadable version.

Sort Projects:	Alphabetically	By Grade Level	By Industry
Grade Levels:	General Math Pre-Algebra Algebra	Geometry Algebra II Pre-Calculus	Statistics Calculus Modeling

NSF

WPI

Industry CIMS WPI

Sample Projects

Taffy Production Line

Download this project

The Problem

Modern production lines have to be designed to be as fast as possible with almost no error. When producing millions of products a day how does a company keep track of it all? The project describes how salt water taffy is made. The process starts with mixing raw materials, which are then baked in ovens and subsequently cooled. The taffy ingredients are pulled, folded and twisted on special pulling machines. Finally, the mixture is put into an extruding and cutting machine which produces pieces of wrapped taffy. In this project students become design engineers. They will need to decide how many of each machine the company needs, how long it will take to make taffy, and how much raw material is needed each day.

Network Analysis

Back to Projects List

Download this project

The Problem

Amtrak has been shown to be a company that does a service to the country, but does not make a profit. Executives at Amtrak have suggested that some of the rail lines, stations and/or trains should be eliminated to allow the company to minimize its losses. A team of consultants has been hired to analyze the rail services that are available in any region and decide where Amtrak needs to concentrate its money and services to best meet the needs of its customers. As a team of consultants you will need to make recommendations in your area of expertise as to what Amtrak should do.

Areas of Application

DEVELOPING INDUSTRY CONNECTIONS

With Whom Do You Connect

- ✓ Friends/Acquaintances
- ✓ Alumni
- ✓ Trustees
- ✓ Business School
- ✓ Hospitals
- ✓ Local Non-Profits
- ✓ Career Development Center
- ✓ Government Agencies
- ✓ Big employer in town
- ✓ Workshops and Conferences
- ✓ Chamber of Commerce
- ✓ Strangers

How Do You Connect

- Ask what they do.
- Listen
- Careful to not limit communications by being a “math professor”
- If they don’t have a “math or mathy” problem that they are working on, you may be able to suggest one to them. That is, how some more math/analysis/stats could help.

Possible Challenges

- Company interested but too busy
- Mathematical content - too high/too low
- Alignment of company & academic timetables
- Getting the right students
- Competition with internships
- Financial support
- Industrial project topic does not line up with faculty's interest
- Climates in industry change

Saying 'I do'

If the fit is good, we may need to consider formal agreements.

Scope of Work, Confidentiality, Intellectual Property
Patents and Inventions, Publications and Presentations

WPI

Bottom line…

Take a Chance! Lean Out!
Adventure Awaits!

CIMS
Center for Industrial Mathematics and Statistics

WPI