2. Evidence of Teaching

I have often told students that it is by attending class that they give themselves the best opportunity to understand the material. This seems obvious, yet students do not always realize that they learn the most when they join in the dialogue that occurs between the instructor and the students when a lesson is going well. Similarly, the best way to appreciate how I teach and what I do to engage my students would be to attend a lecture, sit in on an office hour, or work on an assignment.

To represent this experience, I am including material from the Simulation course I taught in Winter, 2008: a sample lesson plan (with accompanying slides), project assignment (and grading rubric), in-class activity, and a pair of slides from the end-of-term review lecture (done in Dr. Seuss-style). I am also including a hand-out I made for my students when I was an undergraduate recitation instructor with the M.I.T. Math Department. Each of these hopefully provides insight into what I strive to accomplish as a teacher: to engage the students, to take high-level material and give it a practical context to which they can relate, and to try to do it all with humor and humanity.


During the Winter, 2008 quarter, I was selected to serve as the instructor for IEMS 317: Discrete Event Systems Simulation. This course is a degree requirement for Industrial Engineering (IE) majors at Northwestern University, and is frequently sought out by other engineering students interested in gaining familiarity with simulation techniques.

The course was project-oriented; I felt strongly that the best way for the students to use the material covered in class was in the form of simulation projects similar to those they would encounter in the engineering and consulting worlds. All aspects of the class—lectures, projects, our consulting case (a term-long class-participation project designed to tie together all class topics), in-class activities, and the final exam (as well as the review lecture, done entirely in rhyme)—had the goal in mind of making the students more comfortable with doing simulation.
2.1.1. Sample Lesson Plan (Abbreviated), with Lecture Slides

Monday, February 4\textsuperscript{th}, 2008

IEMS 317-0, Winter 2008
Lecture #12

Files to have opened at start of class:
- Announcements\_Winter2008.ppt
- ToPost\_TheCase-NotDell\_Winter2008.ppt
- Output Analysis.ppt

- Announcements (see ppt)
  - Humor/Stuff: Animation: grad student seeing their efforts over five years of their life come to fruition

- NotDell Case: Task #3 (lowest mean cost scenario)
  - Notes: What is intuition behind results we see for darkest colors? What physical properties of a scenario make it undesirable?
  - Notes: Did it work? Did your model with sufficient reps meet the error requirement? (Yes it did. But you should always check.)
  - Notes: Why didn’t you go above (19,7)—especially since you covered below these levels so thoroughly?
  - Notes: Great job covering this many scenarios.

- NotDell Case: Task #4 (risk analysis)
  - Notes: Why did you choose “Roundup” for the demand sample? Would ‘Round’ have been sufficient?

  - Remind students this is ‘testable’ material. Next slide: ‘More on NotDell’, then introduce Task #5 (additional input modeling).

- Add’l Lecture Notes: Output Analysis.ppt (Output Analysis)

  - (slide #215) note this week is HEAVY on stats (yea!!)
  - (slide #216)
    - note that ‘measure of error’ is what drives # of reps (should know that from Project #1)
  - (slide #217) go through entirely
    - ‘Terminating’ is MORE like reality
    - example of ‘time-dependent…’ is avg. # of customers in bank at specific time
    - ‘Steady-state’ will be Project #3—kind of like queueing models
  - (slide #218) read
  - (slide #219) ‘steady-state’ means you don’t care when it’s going to end
  - (slide #220) read
  - (slide #221)
    - IN REALITY: things change… but we model as though they don’t change
    - ‘stationary’: internet is bad example (always growing)
- ‘changeovers’ refers to NOT a flawless change

- (lesson plan abbreviated) …

**Corresponding Lecture Slides**

**Output Analysis**
- “Output Analysis” covers…
  - The design of the simulation experiment (# of replications, which systems to simulate)
  - Analysis of the data generated by the simulation
  - A key goal of output analysis is to produce, or control, a **measure of error** on the simulation performance estimates.

**Output Analysis Overview**

**Types of Simulation**
- There are two fundamental types of simulations:
  - Nonterminating (steady-state) simulation: performance measures are over a conceptually infinite planning horizon
  - Terminating simulation: performance measures are with respect to well defined initial and final conditions.

**Steady-State Simulations**
- A continuously operating (3 shift) production system.
  - The Internet
  - A hospital emergency room
  - A 24/7/365 contact center

**Initial Conditions & Stopping Time**
- Key to steady-state simulation is that the effect of initial conditions (how the system starts) are not of interest, and there is no set planning horizon.
- The goal is to summarize system performance by long run measures after the impact of initial conditions have diminished.

**When is Steady State OK?**
- When the system is truly continuously operating and stationary.
- When non-productive time or down time is ignored.
  - Modeling a 3-shift operation by ignoring changeovers.
- No fixed planning horizon
  - Many supply-chain systems
2.1.2. Sample Project Assignment, with Grading Rubric

IEMS 317, Winter 2008
Ira Gerhardt
Project 1: Garbage Recycling Decision
Approximation due: January 25, 2008
Project due: February 1, 2008

Seymour, a medium-sized Midwestern community, is planning to upgrade the incinerating system of its recycling center to keep up with increasing demand. There are three options to fuel the system: natural gas (NG), bunker oil (BO) and wood (W). Each of the three fuels involves different investment costs, operating expense rates and material cost rates.

Operating expenses are functions of the quantity of garbage processed, which is expected to be 1 million tons during the first year, and growing at a rate of roughly 10% per year thereafter. Operating expenses are $0.50/ton for NG, $0.60/ton for BO, and $1/ton for W.

The material costs also depend on the quantity of garbage processed, and in some cases the price of fuel. For W the cost is $0.10/ton processed. For BO, the cost to process a ton of garbage is $0.02P, where P is the price of a barrel of oil. The cost per ton for NG is $0.40 + $0.001G per ton, where G is the cost of $10^7$ kilocalories of NG.

There are initial investment costs of approximately $6 million for each option. However, for NG and BO these costs must be incurred entirely before start up (call this year 0), while for W $4 million is incurred in year 0, and the remaining $2 million in year 1. Actually, the $2 million in year 1 is a worst-case scenario; far more typical are costs of around $1 million.

The new system is expected to last for 10 years. Naturally, Seymour would like to invest in the system with the lowest net present value of cost (bringing everything back to year 0). But city planners realize that the price of oil, the price of natural gas, and the growth in garbage to be processed are all variable. Therefore, they would also like to manage their risk of incurring excessive costs.

Data on the yearly average price of a barrel of oil for 1983-2008, and natural gas for 1997-2005, are in this file. Please use this data for your input models, even if you believe you have better sources.

The city planners believe that the growth in garbage will be about 10% per year, but could range from 5% to 15%. After further questioning they agreed that these are not even firm lower and upper bounds.

You will need to come up with a reasonable discount rate to use in your net present value calculation [We will not worry about modeling inflation.] Use the Excel NPV function to compute the net present value.

**Approximation:** Develop a spreadsheet that uses mean or most likely values for everything. Turn in two printouts of your spreadsheet, one that shows the results, and the other that displays the formulas. To display formulas Press CTRL + ` (grave accent).

**Project:** Your task is to evaluate the options, make a recommendation, and explain the risks to the city planners. You must look at both the mean NPV and also assess risk in a meaningful way. Your recommendation should balance these objectives. Since accounting will also read your report, an Appendix should justify the input models you chose and the # iterations you used. The Appendix should also give the spreadsheet model with the formulas displayed.
# Example Grading Rubric

<table>
<thead>
<tr>
<th>Project 1 Grading</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name(s)</strong></td>
<td>J. Student</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Category</strong></td>
<td><strong>Points</strong></td>
<td><strong>Attained</strong></td>
<td><strong>Comments</strong></td>
</tr>
<tr>
<td>Report Format (1 page, correct format, Appendix can be longer but not excessive)</td>
<td>1</td>
<td>1</td>
<td>No partial credit. -1 if they miss any part of the format</td>
</tr>
<tr>
<td>Executive Summary (brief summary of results, conclusion if there is one, not introduction to the problem)</td>
<td>1</td>
<td>1</td>
<td>-1 if not concise</td>
</tr>
<tr>
<td>Experiment Design &amp; Analysis (replications and justification in terms of error control)</td>
<td>2</td>
<td>2</td>
<td>Must get desired level of error and solve for reps. Ok to use more reps than needed. +1 for reporting reps, +1 for justification (can be in Appendix).</td>
</tr>
<tr>
<td>Shortcomings (input models, other unknowns)</td>
<td>2</td>
<td>2</td>
<td>To get full credit they must say something about the impact of 1 or more of these shortcomings (e.g., input models without data)</td>
</tr>
<tr>
<td>Tables (Summarize key results in tables; should not include results that are not used or discussed. Must have confidence interval on mean (NPV))</td>
<td>2</td>
<td>2</td>
<td>-1 if they do not have confidence interval on the mean. The other point is for appropriate tables or summaries</td>
</tr>
<tr>
<td>Interpretation of Results (Must translate results to allow understanding of risks and rewards from this project. Must look at more than just mean; must assess risk)</td>
<td>4</td>
<td>3</td>
<td>To get full credit they should address the fact that the results are dependent on input models, such as tornado graphs. Comments on the effect on your output of changing anything in your input model.</td>
</tr>
<tr>
<td>Appendix: Input Modeling (Must justify input models used)</td>
<td>4</td>
<td>2</td>
<td>(1) Need more than histograms to justify distribution choices (e.g., KS, CS, AD). (2) Need better justification for discount rate.</td>
</tr>
<tr>
<td>Correctness of model (logically correct and complete)</td>
<td>4</td>
<td>4</td>
<td>-1 for each logical error</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>
2.1.3. Sample In-Class Activity: *HAT!!*

I frequently provided my students the opportunity to be active participants in class. One technique I utilized was to have them work in small groups on brief simulation problems that would help reinforce their knowledge of the material and their familiarity with the simulation software tool Arena. I put little slips of paper with these problems in a baseball cap that I had with me in class and had a student randomly select one; the groups then had five to ten minutes to design a solution. I present examples of these problems below, with a prepared solution for each.

**Modeling Moments: Set Ups**

A workstation handles ten different types of parts. Whenever a part arrives that is of a different type from the last part that the workstation processed there is a two-minute changeover time to alter the tooling. How can we incorporate this changeover time?

*(1st file, ‘e’ view)* Secret: Define global Variable ‘Last Type’. Immediately after entity creation Assign attribute ‘Part Type’ (uniform discrete), second attribute ‘Part Time’ (constant). Use Decide to see if ‘Part Type’ is equal to ‘Last Type’, if so send on to be processed as-is, if not, Assign ‘Part Time’ equal to ‘Part Time + 2’. After processing, set ‘Last Type’ equal to ‘Part Type’.

**Modeling Moments: Animating Groups of Entities**

In an order fulfillment center, boxes come down a conveyor from time to time. When eight boxes have collected they are moved as a group to a sorting center, and then distributed individually to the appropriate truck. How can we model this grouping and ungrouping, and animate it so we see the boxes move as a group?

*(2nd file, ‘g’ view)* Secret: Use Batch to make group of 8. After batch, Assign picture to GroupBox (picture of 8 boxes together). Use Separate to unbatch, Assign new picture (original picture) of individual box to each.

**Modeling Moments: Skill Sets**

A call center has four basic tasks: taking individual customer orders, taking business customer orders, answering individual customer questions, and answering business customer questions. Operators are rated I-Order (can only take individual customer orders), I-All (can do all individual customer tasks), B-All (can do all business customer tasks), All (can do all tasks). When a customer calls and has been classified (individual or business; order or question), how can we model its request for the right kind of operator resource?

*(2nd file, ‘k’ view)* Secret: Uses Sets. Define a Set for each type of caller, such that the Resources in that Set are the list of operators that are capable of answering that caller’s question.
2.1.4. Review Lecture, Example Slides

During the term, I presented a review slide at the start of any class wherein I continued a previously introduced topic. Towards the end of the term, I realized that the set of review slides effectively told the story of our class. I utilized them in the review lecture I gave the last day of class; that day (March 14, 2008) was also the release date of the movie version of *Dr. Seuss’ Horton Hears a Who™*. In honor of that release (and as a big Dr. Seuss fan), I performed the review lecture entirely in rhyme.

The following pictures are the first two slides from this presentation, with the accompanying verses. The students received a hand-out packet with only the slides, while I utilized the Notes View in PowerPoint to perform the accompanying verses.

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**A Slew of Review**

Our course in 15 slides
(ya know, plus or minus a few),
some color, some black & white,
right here, right now, a slew of review.

Come one, come all, and gather ‘round,
Once again my voice, a melodious sound,
We’ll talk of systems and error and risk,
Of Arena and the death of the floppy disk.

Today has come time for our Slew of Review,
and in honor of Dr. Seuss’s Horton Hears a Who,
Away from your project questions I did take some time,
And have tried to make it useful … and to do it in rhyme.
The lecture lasted approximately half an hour and consisted of an additional 14 slides, covering topics from confidence intervals to linear congruential generators and common random numbers. I feel the lecture was well received; at its conclusion, there was a round of applause from the students, and to this day, I encounter undergraduates in our department who ask if I really gave a lecture entirely in rhyme. But the greatest indicator of the usefulness of the lecture was that my students made it clear by their performance that they were well-prepared for the final exam.

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**Spreadsheet: Review**

- A simulation model consists of INPUTS + LOGIC
- Build the spreadsheet functional relationships first, then add uncertainty.
- Input modeling starts with deciding what are the possible outcomes, then “fitting” relevant distributions.

We began the first day with a spreadsheet or two, the idea was ‘Hey, Excel, at least not something new’. The first item we turned to was ‘What’s the objective to examine?’, and this was before Trunk Monkey and John West Salmon.

If you’re modeling cost, build all the functionality first, You can add the random inputs later, worse comes to worst. With Lab Numero 1 came @Risk, with histograms and such, Project 1 used @Risk too, and after that, not so much.
2.2. 18.03: Differential Equations - Fall, 1997 to Spring, 1999

During my undergraduate experience, I served four semesters as a recitation instructor for 18.03: Introduction to Ordinary Differential Equations (ODEs), in the Mathematics Department at M.I.T. The focus of the class is to introduce students to differential equations (as opposed to algebraic ones), where, rather than identifying the value of a variable that satisfies a set of equations, we try to identify the function whose properties (slope, inflection, etc.) are described. ODEs are the building blocks of much of the research done in engineering, and have applications in several other areas as well.

My goal as a recitation instructor was to provide the students with a multitude of example ODE problems and to review the steps necessary to solve the equations. The following page is a handout I designed to assist students in solving second-order constant coefficient ODEs where the right-hand side is non-zero, with a specific focus on identifying the pit-falls in this type of problem (e.g., see Example 3).
Solving Inhomogeneous Differential Equations

- **What would you use as $y_p(x)$? (do not solve for coefficients)**

1. $y'' + 2y' + 2y = x + e^x$ → Think superposition:
   
   \[ y'' + 2y' + 2y = x \Rightarrow \text{Trial } y_{p1} = Ax + B, \]
   
   \[ y'' + 2y' + 2y = e^x \Rightarrow \text{Trial } y_{p2} = Ce^x. \]

   Check that Trial $y_{p1}$’s do not solve the homogeneous equation:
   
   \[ y'' + 2y' + 2y = 0 \Rightarrow r^2 + 2r + 2 = 0 \Rightarrow r = -1 \pm i \Rightarrow y_h = e^{-x}(c_1 \cos x + c_2 \sin x), \]
   
   and neither Trial $y_{p1}$ solves the homogeneous equation. Thus, $y_p = y_{p1} + y_{p2} = Ax + B + Ce^x$.

2. $y'' - 4y = \cos 2x$ → Trial $y_p = A \cos 2x + B \sin 2x$. Check the homogeneous equation:
   
   \[ y'' - 4y = 0 \Rightarrow r^2 - 4 = 0 \Rightarrow r = \pm 2 \Rightarrow y_h = c_1 e^{-2x} + c_2 e^{2x}. \]
   
   Thus, Trial $y_p$ is good.

3. $y'' + 4y = 3 \cos 2x$ → Trial $y_p = A \cos 2x + B \sin 2x$. Check the homogeneous equation:
   
   \[ y'' + 4y = 0 \Rightarrow r^2 + 4 = 0 \Rightarrow r = \pm 2i \Rightarrow y_h = c_1 \cos 2x + c_2 \sin 2x. \]
   
   **UH OH!!!** Since $y_p$ solves the homogeneous equation, we must multiply the Trial $y_p$ by $x$:
   
   \[ y_p = Ax \cos 2x + Bx \sin 2x, \]
   
   which does not solve the homogeneous equation.

4. $y'' - 6y' + 9y = 2xe^{3x}$ → Trial $y_p = (Ax + B)e^{3x}$. Check the homogeneous equation:
   
   \[ y'' - 6y' + 9y = 0 \Rightarrow r^2 - 6r + 9 = 0 \Rightarrow r = 3 \text{ (null 2)} \Rightarrow y_h = (c_1 + c_2 x)e^{3x}. \]
   
   Since Trial $y_p$ solves the homogeneous equation, and since 3 is a double root of the characteristic equation, we must multiply Trial $y_p$ by $x^2$!!! Thus, $y_p = (Ax^3 + Bx^2)e^{3x}$.

**The Rule:**

If at least one term in Trial $y_p$ solves the homogeneous equation, multiply Trial $y_p$ by the lowest power of $x$ (i.e., $x^l$) such that no term in “$x^l/(\text{Trial } y_p)$” solves the homogeneous equation.

- **Complex Exponentials. An Example:**

  What is $y_p$ (with coefficients) for $y'' + 2y' + 5y = e^x \sin x$?

  \[ e^x \sin x = \text{Im}(e^{(1+i)x}) \Rightarrow \text{Trial } y_p = \tilde{c}e^{(1+i)x}, \tilde{c} \in \mathbb{C}. \]
   
   Our final answer should be $y_p = \text{Im}(\tilde{y}_p)$. Thus, find $\tilde{c}$ by using the original ODE; that is, $\tilde{y}_p$ satisfies:
   
   \[ \tilde{y}_p'' + 2\tilde{y}_p' + 5\tilde{y}_p = e^{(1+i)x} \Rightarrow (1 + i)^2 \tilde{c}e^{(1+i)x} + 2(1 + i)\tilde{c}e^{(1+i)x} + 5\tilde{c}e^{(1+i)x} = e^{(1+i)x}. \]
   
   Thus, $\tilde{c} = 1/(7 + 4i) = (7 - 4i)/65 \Rightarrow \tilde{y}_p = (7 - 4i)e^{(1+i)x}/65$. Finally,
   
   \[ y_p = \text{Im}(\tilde{y}_p) = e^x \text{ Im} \left[ \frac{7 - 4i}{65} \left( \cos x + i \sin x \right) \right] \]
   
   \[ = e^x \left( \frac{7}{65} \sin x - \frac{4}{65} \cos x \right). \]

   (We can confirm that $y_p$ does not solve the homogeneous equation.)