Teaching decision problem formulating and solving skills using spreadsheets

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Abstract

This paper describes a variety of communication media and tactics used in teaching Engineering and Management students to formulate and solve management decision problems using spreadsheets. Many of these problems are framed as optimization models—where students specify decision variables and objectives and constraints as a function of these decision variables. Other problems are solved with simulation models in which some spreadsheet input cells have probability distribution functions and consequently key output cells are described and interpreted statistically. The conceptual modeling/formulation of optimization and simulation decision models is done primarily via thinking and handwritten notes. The data and variable relationships are input by students into an Excel spreadsheet where canned solvers are used as computer subroutines according to parameters set by the students. The author (instructor) uses a variety of communication media (Excel, writing notes on the board, talking, PowerPoint, video) in facilitating students learning to formulate and solve decision problems. The core of this paper explains when to use each media—blending active and passive learning depending upon the item being learned and the context. The principles apply to instruction when software is used to implement problem solving concepts and to other learning contexts where software is integrated with offline learning. Practical considerations are discussed such as how the author deals with different software versions and monitor/font sizes varying among student laptops, his office computer, and the computers used in the teaching lab. The paper concludes with a remaining challenge for which the author has not yet found a good approach.

Introduction

During their junior or senior year, Clarkson University students majoring in Engineering and Management take a course in operations research. In this course, students learn to formulate and solve management decision problems using Microsoft-Excel spreadsheets. Many of these problems are framed and solved as optimization models. In an optimization model, decision possibilities are expressed as variables, and objectives and constraints (equations) are expressed as a function of these decision variables. For example, an investment problem may involve decisions on which stocks to select to maximize total return subject to constraints ensuring that downside risk is limited. In another example, the decisions may be where to insert radiation needles to destroy cancerous cells while minimizing the number of healthy cells destroyed. Other decision problems are analyzed with simulation models in which some spreadsheet input cells have probability distribution functions and consequently key output cells are described and interpreted statistically. For example, given probability distributions of customer arrival rates and service times, simulation models can be used to calculate statistics such as average customer waiting time and the probability that a customer waits more than a specified number of minutes. The primary course objective (as reflected in homework and exam problems) is for the students to be able to take a word description of a decision problem, formulate a mathematical description of the problem in spreadsheet (Excel) format, set the appropriate parameters for solving the problem, and apply canned software (Risk Solver Platform for Education) to solve the problem.

To facilitate the attainment of this course objective, the author (instructor) uses a variety of communication media (writing notes on the board, spreadsheets, PowerPoint slides, and video). The remainder of this paper is organized by communication media and how and when the instructor uses each communication media. In addition to using the best media for a given learning context, by using multiple media in a given class session, student boredom is reduced and different student learning styles are accommodated.

Classroom Communication Media

Writing on the Board

I write on the board most core concepts that the students need to know. Note taking ensures the information enters the students' brains and "we write on the board at about the same speed with which we comprehend information."[1]

A key aspect of decision modeling is framing the problem. After introducing a problem, I may ask the students what additional information they need to know to formulate the model, or I may ask them questions like, "What are the constraints?" Writing on the board facilitates these interactions since I can write the students' answers (sometimes "tweaked" by me) onto the board in any sequence they respond.

Another reason for writing on the board is that I can refer to these notes later during the process of entering the decision model into the spreadsheet. It is possible to do the same with slides but difficult because of only a single projector screen.

Sometimes using the spreadsheet graphical user interface (GUI) is straightforward. Other times the student must execute a series of non-obvious steps in order to accomplish a single task. Writing notes on the board is helpful for these situations. For instance, I may write on the board the following steps to conduct a (single) sensitivity analysis immediately prior to using the spreadsheet GUI:

<u>Parametric Sensitivity Analysis</u>

1. Click New Cell to vary Parameter
2. [click] Risk Solver → [click] Parameter → [click] Sensitivity
3. Link Old Cell to Varying Cell
4. Click on Output Cell
5. [click] Risk Solver → [click] Reports → [click] Sensitivity
   → [click] Parameters (Use ">" twice)

Although the students enter their model into spreadsheets, often the problems are too difficult for them to proceed from word problem statement to spreadsheet model without writing anything down. In these cases, it is better for them to write out their solution on paper. Suppose, for instance, they are asked to add a constraint which models the situation that chairs must comprise at least 10% of the total production of chairs, desks, and tables. I would ask them to try modeling the constraint on their own. Many of them would just stare at their spreadsheets. After

a couple minutes, I would write on the board the following steps and pause after writing each step to ask a student to suggest how the step applies to the example.

Process for Modeling Challenging Constraints
Step 1. Write constraint on paper in your own words.
e.g. chairs must be at least 10% of total production
Step 2. Alter your word description to contain decision variables
e.g. C / (C + D + T) >= 10%
Step 3. Convert into a linear form.
e.g. C >= 0.1 (C + D + T)
Step 4. Convert into standard spreadsheet form for linear models.
e.g. 0.9 C - 0.1 D - 0.1 T >= 0
Step 5. Enter the constraint into your spreadsheet.
Step 6. Generalize the constraint to be parameter driven
e.g. (1 - %) C - % D - % T >= 0

By writing these steps on the board (on their paper), the students develop the habit of executing multiple steps on paper which is easier than trying to do one multi-step process in their heads.

Modeling formulation skills can be developed through a series of building block exercises[2]. As an example building block, I may write on the board the following question and give the students a few minutes to work out the answer on their own before we discuss together as a class:

Question: a port can load either 10 shiploads of [type] X or 15 units of
of [type] Y or 20 units of [type] Z each week.
What combinations of X, Y, and Z can be loaded in 12 weeks?
Answer: (1/10) X + (1/15) Y + (1/20) Z <= 12

Spreadsheets

Over half the time of most classes, the students are using spreadsheets. Sometimes the students learn by watching me play the decision modeler role while they type along in their own spreadsheets. At other times, the students are given time in class to work on the problems on their own after we first discuss them; every few minutes, I will interrupt their exercises to do the next couple steps myself before they continue again on their own. A key aspect is to ensure that the spreadsheet models are well organized and properly documented and highlighted.

Sometimes there are multiple ways to accomplish a task in Excel. Typically, I will begin showing them the most intuitive way to do something (based on the GUI) even if it involves more clicks and takes longer to do and only later show them the less intuitive short cuts. Occasionally, I will make mistakes on purpose since students need to know how to identify and recover from such mistakes.

Spreadsheets are posted on moodle from where students can download them. Before class, I will post spreadsheets that students can use in class to reduce their typing (e.g. data already loaded or model partially built). Sometimes these pre-loaded spreadsheets will contain "poor choices" for

the parameter settings so that students get in the habit of reviewing and adjusting the parameter settings. After class, I post the spreadsheets we developed in class with post-class annotations inserted as comments to highlight aspects of how we developed the model or observations we noted vocally in class.

Although the Risk Solver software should perform the same under different software versions, in practice different versions of Excel (2007 vs 2010) and different operating systems (32 vs 64 bit) yield different results on occasion. Consequently, it is important for the instructor to use the same software and operating system in class which is used by the majority of the students. Ideally, the instructor will test the classroom exercises on all common software platforms prior to entering the classroom. More commonly, when students encounter failures using different software platforms, I will test the exercises myself on that platform to see if there are types of exercises which should be avoided in future class sessions.

I adjust the font size of each worksheet used in class. Typically, I prefer 130% magnification (for easy viewing from the back of the classroom), but if that setting does not show enough of the screen content for a particular worksheet, I may zoom to only 120% or even smaller magnification. It is helpful to practice/rehearse with these font sizes and simulate a smaller monitor size on my personal computer (outside the classroom) so that the experience matches closely with what I will be showing the students in class.

Slides

PowerPoint slides are used less often than spreadsheets and writing on the board. Slides are good for showing graphics (e.g. to visualize the hill climbing algorithm), for items which the students need to be able to reference (but not really learn/memorize), and to convey the gist of some ideas without the students mastering the details. Before an exam, I will use slides to review material the students should have learned earlier but may have temporarily forgotten. (Also I insert some new material into these review sessions and sometimes review the prior material from a different angle or using additional words). Slides are good for covering material quickly. Powell[3] and Felder[4] suggest that the active learning methods of developing spreadsheet models or at least taking written notes is preferred for most learning activities in this type of course. Nevertheless, I try to show at least a few slides every other class session so that the resulting variety of media stimulates student interest.

Videos

Videos are great for showing moving items (e.g. showing a graphical simulation of an automated warehouse). They are good for showing testimonials of executives boasting of the specific value of the operations research methods the students are learning. Finally, videos are good for showing practicing operations research engineers describing their best work[5].

Conclusion and Remaining Challenge

This paper summarizes communication media and tactics used in educating students to model and solve decision problems using spreadsheets.

A decision model will work only if it is completely correct. If any spreadsheet cell or parameter setting is incorrect, the student will get different results than his classmates and sometimes no usable results at all. This challenge is exacerbated by varying levels of spreadsheet competence among the students. A student who has developed spreadsheets during a co-op assignment tends to be considerably faster at spreadsheet typing and navigation than a student who has rarely (and for some students never) used spreadsheets prior to the course. The challenge is controlling the speed of the course delivery so that the slower students can keep up without boring the faster students. When the faster students get bored, they may daydream or multi-task and thus miss a step which results in their models failing as well. When I act as a role model developing a spreadsheet in class, I try to proceed at a pace which can be comprehended by about 90% of the students. Is there a better way to address this challenge of accommodating different student capabilities while retaining the advantages of an interactive instructor-facilitated learning experience?

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