

The Use of Video Tutorials in a Mathematical Modeling Course Taken by Pre-service Teachers

Introduction

Representation is one of the Process Standards that the *Principles and Standards for School Mathematics* (NCTM, 2000) lists as useful for obtaining and applying mathematical skills and concepts. The ability to clearly and accurately represent mathematical ideas is key to analyzing real world problem situations. The National Council of Teachers of Mathematics (NCTM) advocates that K-12 mathematics courses should incorporate all aspects of mathematical representation. One significant aspect is to “use representations to model and interpret physical, social, and mathematical phenomena” (NCTM, 2000 p. 67). This is fundamental to understanding the connections between concepts and applications and is the heart of mathematical modeling. The Committee on the Undergraduate Program in Mathematics (2004) has recommended that a mathematics degree include a course that focuses on real-world mathematical applications. They recommend a course that emphasizes all aspects of the solution process from the development of a model to the interpretation of the numerical values the process yields. This type of course will benefit all mathematics majors—not just those preparing for education-related careers.

Mathematical Modeling at Virginia Commonwealth University (VCU) emphasizes building accurate models and analyzing model solutions. With a focus on problems that reflect real-world situations, this is a college course that incorporates many of the NCTM (2000) guidelines on the development and use of mathematical models. To meet state certification requirements, this is a required course in the degree tracks for pre-service middle and high school mathematics teachers. Each semester, the class is also comprised of students preparing for

careers in operations research, engineering, or other mathematics-related fields. This diverse population provides for a dynamic learning environment and an opportunity for pre-service teachers to realize the importance of mathematical modeling to a variety of career paths.

To present students with a more accurate picture of the role technology plays in modern applications of mathematical models, student versions of state-of-the-art software play an integral role in our course. This use of technology adds its own set of challenges to course instruction, however, and previous offerings of the course have shown that emphasis unintentionally shifts from the modeling process to software specifics. With an interest in keeping the focus of our course on the important aspects of the modeling process, we designed a series of video tutorials to help students master the software details that must be understood before they can successfully develop mathematical models. The modeling course, the video tutorials, and an assessment of the usefulness of the tutorials are described below.

Mathematical Modeling Course

The textbook for the course is *Spreadsheet Modeling and Applications – Essentials of Practical Management Science*¹ (Albright & Winston, 2005). As the title reflects, a spreadsheet software program – Microsoft Excel – is the tool used to develop mathematical models. The course is taught in a computer lab where all class presentations, examples, and assignments take place with the use of technology. Each student has access to a computer for the entire class period. Occasionally the instructor uses Microsoft Powerpoint presentations to highlight the important points of the mathematical content being covered in each class session. However, lecture plays a minimal role as most class time is spent with students engaged in developing and evaluating mathematical models. Modeling activities take place as a whole class, in small

¹ The textbook for the course when this project began was *Practical Management Science: Spreadsheet Modeling and Applications* by Winston & Albright (2001). We note that it is very similar to the textbook we discuss here in its choice of mathematical models, its choice of software packages, and its emphasis on the use of spreadsheets.

groups, and individually. A student's grade is determined by a variety of activities including tests (midterm and final exam), quizzes, homework assignments, and in-class discussions. Due to the minimal amount of lecture, heavy emphasis is placed on class participation. Specific details of the syllabus and course topics can be found on the course website. [The URL for the course webpage has one author's name in it so the link to course website will be added after the review process is complete.]

By design, the course emphasizes model development and solution analysis. Properties of various model classes are discussed. Students are also taught to assess the validity, accuracy, and sensitivity of models and model inputs. Discussion then moves towards analysis of resulting solutions and interpreting the mathematical solutions for lay users. While algorithms are sketched, they are not discussed in great detail, as most algorithms used for these models are complex and beyond the scope of the course. Students have ample opportunity in other mathematics courses to study methods of problem solving; often in these courses, there is insufficient time to spend on careful model development and solution analysis. We place emphasis on these things to balance students' perspectives. Nevertheless, solutions cannot be analyzed until they are provided. This is where software enters the picture.

Microsoft Excel and Excel add-in programs are used for all examples as well as for in-class and out-of-class assignments. Solver is an add-in that is included in the Excel software but before use must be loaded through the Tools menu. It allows the user to optimize a target function subject to constraints on the variables provided within the spreadsheet. The other add-ins used in the course (PrecisionTree and @Risk) were designed by [Palisade Corporation](#), and student versions are included on a CD-ROM that accompanies the textbook. They are also available for purchase [online](#). PrecisionTree generates a tree diagram with probabilities and

payoff values for each stage of a decision process. With user-provided information for a given scenario, the tool generates an analysis of the mathematical model and provides the user with information on the ideal decision making path through the tree. @Risk is a simulation program that generates a variety of possible outcomes for the situation the user provides within an Excel spreadsheet. It is useful for estimating the probability that each outcome scenario will occur. These add-in modeling tools are powerful for analyzing and building mathematical models. While they represent the state of the art in solution methodology, they are not the only software options available. Thus it is important to note that the course is not dependent on using these specific software packages, but rather on building the kinds of models they are intended to solve and on interpreting the model solutions they provide.

When teaching Mathematical Modeling in Spring 2003, the instructor noted several technical aspects of Microsoft Excel and the add-ins with which students repeatedly had difficulty. Working with undergraduates who have not had much exposure to the course software, the instructor found she was spending excessive amounts of time answering software questions—valuable time that could have been used to help students develop the skills to build mathematical models or to understand modeling concepts. Furthermore, many of the questions were repetitious and focused on basic software functions (e.g. “Which button starts the simulation?”) rather than on modeling issues. The instructor (also an author of this paper) decided that a set of video tutorials could cover the technical skills students need to successfully run the software and free class time for the important aspects of mathematical modeling inherent in the recommendations provided by various mathematical organizations (NCTM, 2000; CUPM, 2004).

Video Tutorials

Four tutorials were designed, one for each of the Excel add-ins (Solver, PrecisionTree, and @Risk) and one on building a data table. Many of the course assignments required students to build data tables—an advanced Excel capability that requires several user steps and does not have its own “wizard”. Based on previous experience in teaching the course, students have trouble with the Excel commands needed to build a data table. Thus, we felt it was important to cover this skill in a tutorial. Each tutorial was created using freely available software, Microsoft Producer, which is an add-in to PowerPoint. This software allows the user to enhance a PowerPoint presentation with video screen capture and audio voice over. In the case of the tutorials, screen captures of the creation of a data table or use of an Excel add-in were added alongside a series of PowerPoint slides listing the steps needed to perform the skill upon which the tutorial was based. To tie the images together, a script describing the important details of each stage of the tutorial was written. The script was recorded as an audio voice over and added to the presentation to provide explanation and support for the visual details provided by the slides and the video images. The completed tutorials along with a more detailed discussion of their design can be found in Author (2005).

The tutorials were posted on the Mathematical Modeling course website. [The URL for the course webpage has one author’s name in it so the link to course website will be added after the review process is complete.] The students were advised to access a particular tutorial one week before the skill covered by that tutorial was needed in class. The tutorials remained available throughout the semester so that students could refer to them as needed. Data tables were required early in the semester, so the data tables tutorial was available the first week of class. The other Excel add-ins were introduced throughout the course, each at least a week before the corresponding software was used in class.

As is often the case when using freely available software, the tutorials created with Microsoft Producer are not as polished as they might be if they had been designed with an expensive program or by someone with extensive experience in instructional technology. We had no budget for the design of these tutorials. In spite of the program's limitations, we were pleased with the finished product and with the students' experiences in using the tutorials. With access to these same tools (Microsoft Producer and PowerPoint), we believe that other educators wishing to create similar tutorials for their courses would find the result useful and effective.

Mathematical Modeling Example

The Solver add-in is useful for solving a problem involving the development of a linear program. Students are given the following example of such a problem:

Suppose you go to your local burger joint for lunch. You have determined that, in order to stay awake for your afternoon classes, you need at least 1150 calories and 35 grams of protein. A burger costs \$3 and has 450 calories and 25 grams of protein. A serving of fries costs \$1 and has 350 calories and 5 grams of protein. You are a college student on a budget, so you want to spend as little money as possible. How many burgers and how many servings of fries should you buy?

If the number of burgers and servings of fries to buy are labeled x_1 and x_2 , respectively, then the resulting linear program is:

$$\begin{array}{ll} \text{Minimize} & 3x_1 + x_2 \\ \text{Subject to} & 450x_1 + 350x_2 \geq 1150 \\ & 25x_1 + 5x_2 \geq 35 \\ & x_1, x_2 \geq 0 \end{array}$$

Solving this linear program graphically and algebraically would allow a student to arrive at an optimal solution. However, if any of the numerical values change, then all of the work would need to be done again. After several iterations to explore the changes that result in the solution set, the process has been reduced to an exercise in algebraic manipulation. By using Solver, students can quickly see differences in solutions based on changes to the mathematical model. Course time can be spent on meaningful discussions on the best model for the problem situation or analyzing a variety of different solutions. Furthermore, graphical solutions are only practical for two decisions (and in fact impossible beyond three!) Using Solver allows students to see that linear programming is generalizable to larger and more complex decision scenarios. We do not advocate abandoning the algebraic and graphical solutions methods altogether, but after students have learned to work these types of problems by hand, there are many benefits to studying models with software tools like Solver.

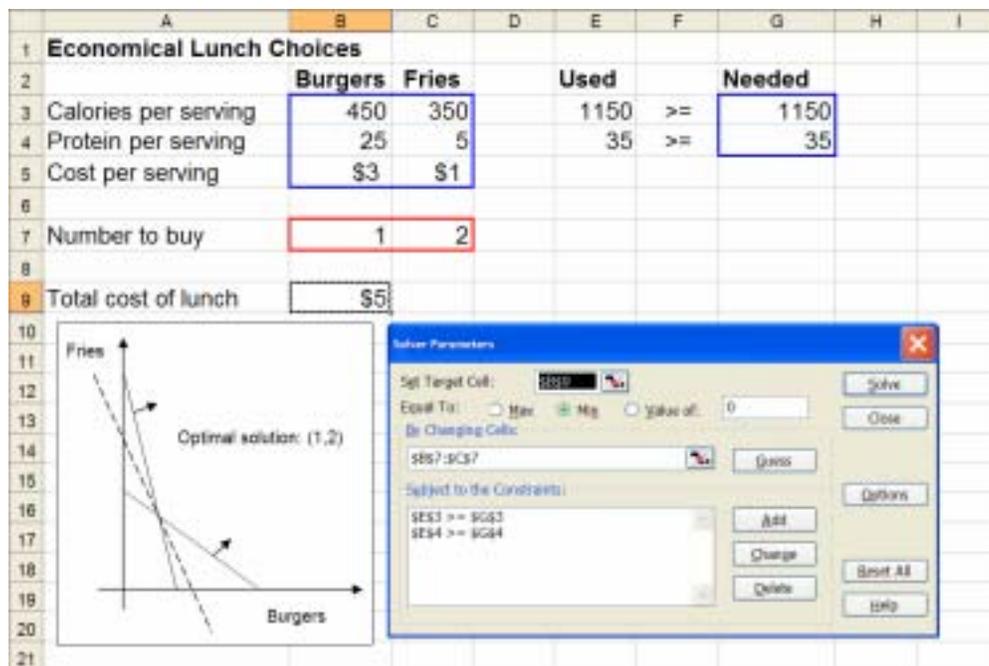


Figure 1. Excel Spreadsheet with Solver Data for Economical Lunch Choices Example

As is the case with many software programs, Solver requires that the information be provided in a specific format. While the algebraic method requires solving a set of equations in two variables, finding the optimal solution to this situation using Solver involves changing cells (instead of labeling variables), a target cell (i.e. the objective value for the situation), and the declaration of problem constraints in a Solver dialog box (instead of constructing and solving linear inequalities). These details are covered by the Solver tutorial which students view before the class period in which this example is worked and discussed.



Click here to view the Solver tutorial: [This link is to take you to Solver Tutorial.htm in the Solver folder uploaded as supplemental material. Since the folder was added separately, the link may not work properly. Click on “Solver Tutorial.htm” in the Solver folder to access the tutorial.]



Click here to view video of a student using the Solver tutorial: [This link is to take you to a video of a student using the Solver tutorial. The video was uploaded as a separate video file and, as a result, the link may not work properly. Click on “Student Using Solver.wmv” to view the video.]

Students have access to the tutorial in case they need to refer to it whenever Solver is appropriate for working a problem. Since the tutorial helped students become familiar with how to designate changing cells and the target cell in Excel and how to use the Solver dialog box to

specify the constraints, the instructor does not have to spend time on these details in class. As a result, more examples are covered during the class period and more discussion on the properties of linear programs and how to interpret the resulting solution follows.

Assessment of the Usefulness of the Tutorials

Anecdotal evidence of the amount of time spent fielding software-related questions revealed that the tutorials provide students with the technical details needed to develop a basic data table and run the Excel add-in tools. As a result, class time was available for more important matters. However, we conducted a formal analysis with an assessment instrument designed to determine whether the tutorials were effective in helping students learn the basic features of the software. The questions were developed to assess if students understood the software features covered by the tutorials, recognized output from specific point-and-click commands, and understood the purpose of the Excel add-ins they were using. They did not assess student understanding of mathematical modeling concepts or other course content. All 22 multiple choice questions were given as a pre-test during the first week of the semester. Students were encouraged to answer the questions to the best of their ability in spite the fact that the questions addressed software components which were most likely unfamiliar to them. After being given time to view a tutorial, students were given the same pre-test questions related to that particular tutorial as a post-quiz. The post-quiz was given before the software features covered by the questions were used or discussed in class. A code word was embedded in the audio of the tutorial and students were asked to provide it on the post-quiz to ensure that they had viewed the tutorial.

Table 1 contains a statistical summary of the number of questions answered correctly on the pre-test and post-quiz for each tutorial. This assessment was conducted with students in the

Spring 2004 and Spring 2005 sections of Mathematical Modeling. Data for a student was used in the calculation of these statistics if the student answered all of the questions on the pre-test and on each of the post-quizzes. Of the students enrolled in each section, 80% completed all assessment items in Spring 2004 and 67% completed all items in Spring 2005 which resulted in complete data for 38 students. Five questions each were devoted to the Data Tables and Solver tutorials. The remaining two tutorials (Precision Tree and @Risk) were each evaluated with student responses to six questions.

Tutorial	Pre-Test		Post-Quiz	
	Mean	SD	Mean	SD
Data Tables	1.55	0.86	2.53	1.54
Solver	1.39	0.92	3.50	1.06
Precision Tree	1.34	0.94	4.29	1.61
@Risk	1.21	0.96	3.47	1.77

Table 1. Summary of Pre-test and Post-quiz Data for Each Tutorial

Students began the semester with the ability to answer approximately one question related to each tutorial correctly. A t-test of the pre-test/post-quiz differences at the 1% level of significance was used to determine whether the students correctly answered more than one question after viewing the tutorials. The statistical analysis revealed that for each tutorial the mean number of correct post-quiz questions was significantly larger than the mean number of correct pre-test questions. Based on this assessment, the tutorials were successful at helping students become familiar with the software features for which the tutorials were developed.

While the results reflect a significant increase in pre-test/post-quiz responses for the Data Tables tutorial, the average number of questions answered correctly on this tutorial was smaller than the average number of post-quiz responses for the other three tutorials. This was the first tutorial the students viewed. Therefore, we suspect that students were uncertain of what was expected of them on the post-quiz and this resulted in the lower number of correct responses.

Conclusion

A solid understanding of mathematical modeling requires a blend of mathematical skills and conceptual understanding. The technology available today reduces but does not eliminate the need for skills. The mathematical modeling course described provides the appropriate balance of skills and concepts and places significant emphasis on the use of technology. To ensure that they are equipped with the ideal mix, this kind of course is essential for pre-service teachers. They need a solid understanding of mathematical modeling when they enter the classroom and prepare lessons that – in this technological era – are heavily application and concept-based. Teachers also need the ability to appropriately demonstrate mathematical modeling for their students. We found that the design and use of video tutorials to help students with the technical skills needed to successfully use the software were helpful with time management and skill practice issues. As a result, the course instructor was able to focus on the important aspects of mathematical modeling – the development and study of models. We believe that teachers at all levels of the education hierarchy with software skill development needs will find similar tutorials helpful for their situations.

References

Albright, S. C., & Winston, W. (2005). *Spreadsheet modeling and applications – Essentials of practical management science*. Duxbury Press.

Committee on the Undergraduate Program in Mathematics (2004). Undergraduate Programs and Courses in the Mathematical Sciences: CUPM Curriculum Guide 2004. Washington, DC: Mathematical Association of America.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

Winston, W., & Albright, S. C. (2001). *Practical management science: Spreadsheet modeling and applications*. Duxbury Press.