Captivate Your Students' Minds: Developing Interactive Tutorials to Support the Teaching of Spreadsheet Modeling Skills

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Abstract

Kolb’s experiential theory of learning, later modified by McCarthy to develop the 4MAT model, shows that active experimentation is a large part of learning for all types of learners. We use the 4MAT model as the theoretical underpinning to explore and develop some illustrative interactive tutorials to support the teaching of OR/MS spreadsheet modeling. Due to a much shallower learning curve on the new generation of screen capture technology, the design and creation of such spreadsheet support modules can now realistically be done by individual faculty in a reasonable amount of time. Three levels of interactivity are used in the modules to match the learning stages of the 4MAT model. We discuss implementation issues with current screen capture software and the benefits and limitations of this approach for supporting the teaching of spreadsheet modeling in OR/MS.

1. Introduction

Bodily’s (1986) seminal work on use of spreadsheets for end-user modeling in OR/MS propelled the academic community to embrace spreadsheets as a tool for teaching OR/MS modeling. The argument is that the spreadsheet environment provides interactive modeling opportunities which allow end-users to incrementally develop the model and gain better insight into their models and the process of model development. While the argument of better understanding of the models by the end-users may be valid, it is not clear how effective the academic community has been in imparting the knowledge of model development to managerial end-users through spreadsheets or otherwise. Researchers (Sokol, 2005; Grossman, 2004; Powell, 2001) point out that even though modeling is considered to be one of the most important skills for students to learn, it is the most difficult and least-developed area in OR/MS education due to the nature of the modeling process. Spreadsheets further added their own sets of challenges. Students or managerial end-users often do not have the required spreadsheet proficiency and thus spend more time in learning spreadsheet commands and techniques than in absorbing the modeling process.

There are a number of tutorials and software support available in the OR/MS area that try to address the issue of spreadsheet proficiency by mostly concentrating on teaching the details of the software. In this study, we explore the potential of using some of the recent screen capture software to create tutorials with multiple levels of interactivity that can support students as they solve an OR/MS problem in a spreadsheet environment. The tutorials are designed to guide the students’ thought process through parts of the spreadsheet model development by allowing the students to identify model parameters and variables and validate their reasoning and spreadsheet logic.

We first discuss the work done in the areas of teaching OR/MS modeling and use of interactivity in teaching and learning to present our motivation for using screen...
capture software to introduce interactivity in OR/MS teaching. In the subsequent sections, we provide detailed descriptions of the interactive modules that we created for teaching students how to use Excel to implement two types of OR/MS models, namely, Data Tables, and Regression Analysis. We hope that our work can provide a guide for the academic community to the potential that screen capture software has to support the teaching of OR/MS spreadsheet modeling.

2. Background

2.1. Spreadsheets, Modeling and OR/MS.

During the last decade, spreadsheets took center stage in the effort of teaching basic modeling skills in OR/MS due to the pioneering work by Bodily (1986) and later by Savage (1997). Today, the benefits of spreadsheets are well documented and the majority of introductory OR/MS texts are spreadsheet-based (see, for example, Powell 1995, 1997, 2001). Indeed, the use of spreadsheets is so pervasive that many now caution not to lose sight of the modeling heart of OR/MS versus the juggernaut of focusing on spreadsheet software keystrokes in our teaching. A number of researchers created various multimedia tutorials to teach spreadsheet skills outside the classroom so that class time can be devoted to teaching concepts and modeling aspects of OR/MS (Albright et al., 2001; Troxell, 2002; Seal and Przasnyski, 2003; and Hardin and Ellington, 2005). Many of the authors who created the modules or tutorials to supplement their teaching commented on the varied spectrum of student abilities, and so one of the main benefits of the tutorials was to provide students with a means to work at their own pace and catch up on any spreadsheet deficiencies they may have, without taking time away from class. Research shows that having tutorials available to illustrate features that require spreadsheet skills is pedagogically beneficial (Daellenbach and Petty, 2000; and Hardin and Ellington, 2005).

But OR/MS is about modeling and concepts, and not about spreadsheet skills. Powell (2001) argues that "the heart of Management Science is not the science of optimization or simulation, but the art of reasoning logically with formal models". He describes a list of modeling skills (what) OR/MS instructors should be teaching without referring to any particular methodology (how) in teaching it. Grossman (2004) states that "O.R. researchers have not developed methodologies for modeling unstructured business situations" and "without research results to guide [OR/MS professors], it is difficult to know what to teach, much less how to teach it". A recent article by Sokol (2005) confirms that, even though modeling is considered to be one of the most important skills for students to have, "it appears to be one of the least-developed areas in O.R. education."

A question thus naturally arises: what is being done to support teaching OR/MS spreadsheet modeling skills to students? There are some support materials using computers and multimedia to improve learning OR/MS concepts and modeling skills by end-users (see e.g., Cochrane’s (2001) "Who wants to be a millionaire" decision analysis game; the MENTOR project by Belton and Scott (1998) and Belton et al., (1997); and the IFORS tutorial project at IFORS’s website (1) headed by Moshe Sniedovich at the University of Melbourne). Researchers have also tried to provide some guidance to deal with the issue of teaching modeling, a rather difficult task given the nature of the topic. Powell (2001) stresses that OR/MS instructors should teach basic modeling skills such as numeracy and logical skills, data organization, categorizing variables, modularization and sensitivity analysis, and pattern analysis before teaching OR/MS tools. Grossman (2004) suggests embracing spreadsheets fully into the modeling process but also advises to make the distinction between modeling and spreadsheet programming. This research illustrates that students need to have a certain level of comfort with Excel spreadsheets before they learn to use them for modeling. The leap from learning spreadsheet programming to OR/MS modeling is huge however. Many students need to practice the spreadsheet mechanics in more structured model applications to help make this transition easier. In this paper, we try to create tutorials based on models of learning theories to accomplish the above task.

2.2. Learning, Interactivity and the 4MAT model.

Education theories suggest that engaging learners by using a variety of interactive media will improve learning outcomes (Barnes, Scutter and Young, 2005). We posit that while such a learning environment is

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(1) http://www.ifors.ms.unimelb.edu.au/tutorial
provided by the instructors in classrooms and during office hours, students usually do not have such support available to them outside the classroom (with the possible exception of study groups) where the students again can get interactive support. Yet, proper use of interactive multimedia systems that incorporate learner control, feedback, and hyperlinked information structure can provide a positive impact on learning (Gay, 1986; Kinzie, 1990; Kozma, 1991; Schaffer and Hamafin, 1986) and allow students to learn complex concepts on their own outside the classroom and internalize it better. In fact, Kolb’s experiential theory of learning (Kolb, 1976, 1984, 1985) later modified by McCarthy (2000a, 2000b) to develop the 4MAT model shows that active experimentation is indeed a large part of learning for all types of learners. We use the 4MAT model as the theoretical underpinning for incorporating interactivity as part of active learning. The essentials of the 4MAT model are presented in Figure 1 where student learning is presented as part of continuous cycle. Each quadrant represents a dominant learning style as defined by the learning activities pursued. Figure 2 indicates how the course pedagogy is integrated into the learning cycle. Finally, Figure 3 shows where different types of interactive modules can be introduced to support more activities of the learning cycle.

The activities in each of the quadrants are examples of tasks performed in each area as one moves from one to the next. For example, Practice and Extend are the two tasks that are typically performed by the individual in moving from Abstract Conceptualization to Active Experimentation.

Figure 1: The 4MAT Model Learning Cycle.

Figure 2: Teaching Components that Support the 4MAT Learning Cycle.

Figure 1 depicts the learning cycle where an individual typically starts the learning with Concrete Experience, followed by Reflective Observation. This is followed by Abstract Conceptualization that finally leads to Active Experimentation.
Figure 3: Interactive Modules Cover More Activities in the Learning Cycle

Figure 3 shows the scope of different interactive modules to support student learning through multiple stages of the learning cycle. The idea is to go beyond the imagine, inform and practice activities and help students through the extend and refine activities. We suggest that such support is integral to enhancing students' understanding of the modeling process in OR/MS and therefore can help the student transition from spreadsheet programming to modeling better.

In this paper, we want to show how the screen capture software, specifically Macromedia Captivate, can be used to introduce interactivity outside the classroom and support learning of OR/MS concepts and spreadsheet modeling. Our intention is to develop student spreadsheet skills and provide validation of the steps used to identify model parameters and variables as students learn to transition to the modeling process.

3. Design of the Interactive Modules

Haseman et al., (2002) state that successful interactive modules should use examples, practice, feedback, self-pacing, user control, and questions. We use their classification, based on Laurel's work (Laurel, 1986), to define our degree of interactivity along three dimensions: 1) frequency (of user input and responses), 2) range of choices (of interactive features available to the users), and 3) modality (transformation and presentation) of information. We have multiple modalities in terms of visual elements, and we developed modules with three levels of interactivity by varying the options available for the first two dimensions. Currently, we have chosen not to implement an audio component in the tutorials, mainly to allow faster download times for students. However, including audio in the tutorials is straightforward, and if desired, can be done quickly and would be one more way to increase the modality.

We included interactivity features such as prompts, hints, questions and feedback, context sensitive user control and navigation where the level of interactivity in each of our modules was determined by the nature of the support needed for the various quadrants of the 4MAT model. Figure 3 shows that the following three levels of interactivity are needed:

1) **Low interactivity modules** mainly demonstrate concepts, keystrokes, and the mechanics of performing a particular task. Here the focus is on demonstrating spreadsheet mechanics and OR/MS modeling concepts, i.e., the imagine and inform activities of the 4MAT model, and student interactivity is primarily limited to controlling the pace of learning. These are similar in nature to the screen capture modules packaged with some textbooks (for example, Chase et al., 2006) and the tutorials developed by Hardin and Ellington (2005).

2) **Medium interactivity modules** increase both the range of choices and the frequency of interaction as students are asked to take part in a concept oriented exercise. User inputs are limited and used mainly to support the practice activities in the 4MAT model, though a certain amount of inform is still carried out. These exercises help validate student comprehension of the modeling examples taught in the low interactivity modules and support students as they practice spreadsheet mechanics.

3) **High interactivity modules** offer a high range of choices and frequencies including intermediate help and more elaborate feedback. These modules are for supporting the Active Experimentation (Act) part of the 4MAT model. The concept oriented exercises in these modules provide further practice for the students and ask the students to extend simple modeling concepts to a new problem, which help students validate how well they can identify new model parameters and variables. The more elaborate feedback system allows students to see whether they fully comprehend a spreadsheet modeling concept and, if necessary, refers them to materials that present the skills they should
be utilizing and the concepts they should be extending to help them refine their learning.

4. Development of Interactive Modules

In this paper, modules with different levels of interactivity have been developed for two different modeling applications, simple linear regression (SLR) and sensitivity analysis using data tables (DT). Each module is classified as either low interactivity (LI), medium interactivity (MI) or high interactivity (HI) for a total of seven modules across the two modeling applications (SLR-LI, SLR-HI, DT-LI1, DT-LI2, DT-LI3, DT-MI, DT-HI, SLR-HI). The SLR-HI module actually includes a hybrid of medium interactivity and high interactivity approaches to effectively illustrate different Captivate features and implementation issues.

Storyboarding is a crucial step for successfully integrating various interactivity features with the modeling concepts at all levels of interactivity modules. Before storyboarding, the faculty member must have a clear picture of what spreadsheet skills and modeling concepts are to be stressed for a particular application topic. For example, the modeling concept that is critical for simple linear regression and sometimes hard for students to correctly perform is the identification of the independent and dependent variables. Once the student can correctly identify the variables, spreadsheets can be programmed to generate the appropriate output results using whatever spreadsheet procedure the instructor prefers.

Storyboarding starts by defining an example problem, collecting and organizing data, and developing a preliminary model from which instruction will start. Regression modules SLR-LI and SLR-HI both start with a university admissions problem where data from last 8 years on the number of applicants and possible independent variables are entered in a formatted spreadsheet table. The Macromedia Captivate screen capture software allows an instructor to record onscreen activity to create a software demonstration of a spreadsheet procedure for performing simple linear regression. The storyboard should script the sequence of keystrokes to be used, the textual or aural narration to be included, and the parts of the online screen activity to be emphasized in the recording. Captivate, when set to Demonstration recording mode, records the selected keystrokes, narration, and spreadsheet screen activity. This recording creates a series of slides that contain the animation associated with the performed keystrokes in low interactivity modules, which can be edited later by the instructor to align more specific details and points of emphasis with the storyboard.

Figures 4a and 4b show the process diagrams for the storyboard section and describe how a modeling concept (the identification of the variables in simple linear regression) is scripted for a simple linear regression. The instructor may choose to emphasize the modeling concept in audio narration or by adding caption boxes at key points on the recorded screen slides. We implemented the latter approach in SLR-LI our low interactivity tutorial.
Captivate also contains a Simulation recording mode that adds user interaction without requiring scripting skills and is used to create the initial screens for the medium and high interactivity modules. During playback of the slides created in Simulation recording mode, the user is expected to click on the same keystroke options that the instructor used during the recording in order for the tutorial to proceed. This helps the user practice many of the spreadsheet mechanics and receive feedback when inappropriate Excel options are selected. For example, in SLR-HI, the tutorial will not advance to the next step of the regression command until the user actually clicks on Excel’s Tools menu option inside the tutorial. When the user clicks in the wrong place, a textbox prompts the user what to do. To prevent frustration for users who are not familiar (or sometimes too familiar and thus bored) with the expected sequence of Excel commands, it is necessary to storyboard branches into the process diagram that allow users to navigate to other parts of the tutorial, receive different feedback messages or to exit altogether. Fortunately, adding menu button options on any screen that branch to different slides within the tutorial is easy to do and can be done after the initial simulation recording is completed. For more details about features and limitations of Captivate, please see Appendix 1.

Our second set of attached modules is a series of five interactive tutorials that have been created to help MBA students understand the modeling concept of sensitivity analysis using Data Tables. These tutorials illustrate the different stages of the 4MAT model. The modeling concept that is needed for a one variable sensitivity analysis is the identification of the uncertain input variable and the key output variable(s) as well as identification of relevant values for the input variable. Compared to the regression application, there is a much steeper Excel learning curve for implementing sensitivity analysis with Data Tables and so more support at all stages of the 4MAT learning cycle is needed. Three of the five tutorials include low interactivity as these three tutorials focus on demonstrating the concept of sensitivity analysis and the spreadsheet mechanics required for Data Tables. The first low interactivity tutorial, DT-LI1, is actually a Flash document that was programmed to illustrate the internal logic of what the Data Table command does and how it performs sensitivity analysis. The second low interactivity tutorial, DT-LI2, uses Captivate to illustrate...
the spreadsheet mechanics for the Data Table command in Excel while the third tutorial, DT-LI3, illustrates how the Data Table structure should be set up in Excel given pre-identified input and output variables. The fourth tutorial, DT-MI, has medium interactivity and allows students to practice the spreadsheet mechanics for a given Data Table structure and reinforces the modeling concept of the appropriate Data Table structure for the demonstrated problem. The last tutorial, DT-HI, is a high interactivity one that extends the modeling concept to a variation of the original problem as it asks the students to define the Data Table structure and fill in the table for a new set of input and output variables. This last tutorial also contains an assessment quiz at the end that asks students more questions about Data Tables to evaluate their understanding of the Data Table logic and supporting spreadsheet commands.

The Data Table tutorials were created to support sensitivity analysis in a Financial Modeling elective (which is why the example uses a pro forma statement application) and prepare students for a large Financial Modeling case that was about to be assigned. While Data Tables are demonstrated during lecture, many students require more time to grasp the spreadsheet mechanics and/or modeling concepts. The lack of understanding of the spreadsheet mechanics is a barrier in understanding the sensitivity analysis modeling concepts. Therefore, students must integrate both the mechanics and concepts in their thought process in order to have full mastery of the tool before they can extend sensitivity analysis to new applications. Providing demonstrative and interactive support outside of class allows students to work on the parts that they do not fully comprehend and practice putting it all together at a pace that is appropriate for their individual needs. The role of the tutorials therefore is to support student acquiring necessary spreadsheet modeling skills, at their own pace, so that class time can be spent discussing the more advanced modeling concepts such as what values to use for the input variable and how to interpret the Data Table results.

5. Assessment

We field tested the use of simple linear regression interactive modules in an undergraduate Production Operations Analysis course with 48 students. Early versions of the SLR-HI and SLR-LI tutorials that were designed to help students extend the simple linear regression logic to new problems were made available one week before the first midterm examination. The students were told that the tutorials were optional and that the instructor thought the interactive tutorials would provide an excellent resource for studying for the hands-on component of the exam. Student usage of these tutorials was tracked (unbeknownst to the students) via Blackboard, an on-line course management system, where it was observed that 44 of the students watched the demonstrative tutorials while 30 students used the highly interactive tutorials to prepare for the exam. Many students chose to view the tutorials more than once, with several students studying the set of tutorials between 10 and 20 times.

Student performance on the regression component in the examination (parts III-V in Appendix 2) was compared to the usage of the high interactivity tutorials to assess if the tutorials could potentially have had any impact on student learning. The correlation between these two variables was 0.227, significant at the 7% level, which shows a slight positive relationship. This relationship was slightly stronger (0.254), significant at the 5% level, when we excluded the usage of the high interactivity tutorials that the instructor thought the interactive tutorials would provide an excellent resource for studying for the hands-on component of the exam. Not surprisingly, it was found that using the tutorials only hours before the 9:00 A.M. exam to “cram for the test” had no statistically significant correlation with student’s performance on the exam material. Using student GPA as a measure of aptitude, there was a 0.124 correlation (p-value = 20.41%) between the student’s regression exam performance (parts III-V) and his/her GPA versus a 0.314 correlation (p-value = 1.77%) between the student’s GPA and performance on the rest of the exam, including the other forecasting parts. Thus student aptitude had a stronger positive.
relationship with student performance on other material taught in the class. Interestingly, watching the low interactivity tutorials did not appear to have an impact on student performance for the regression material (correlation of 0.10 with a p-value of 25.68%). There was however a relatively stronger relationship between student performance on the regression question and the rest of the exam (0.304 with a p-value of 2.10%), suggesting that students who were better prepared overall also did better on the regression question. A factor to consider that was not addressed in our experiment is that by being prepared for the rest of the exam, students had more time to complete the regression portion of the test. It was noted during the examination that some students did not have much time to spend on the regression section which biases our results. These preliminary results suggest that when used appropriately (i.e., not for cramming), the high interactivity tutorials may help students implement regression concepts and spreadsheet mechanics better. These results provide the preliminary impact of the limited number of prototype tutorials created and evaluated to date and at this stage of research are purely exploratory in nature. These tutorials are currently being beta tested and as more tutorials are developed and refined, a more sophisticated experimental design, including a control group, will be required to investigate more formally questions such as whether the tutorials are effective for helping students who normally do not fare as well on exams.

In addition, after students received their exam scores back, they were surveyed about their perception of the value of the tutorials. This survey is shown in Appendix 3 and was distributed to students stating that the purpose of the survey was to identify whether developing these tutorials was a good use of the instructor’s time. Did the students want more tutorials or other resources such as more study guides, games, etc? The impact that both the low and high interactivity tutorials had on student attitude towards learning the material was very positive. Tables 1 and 2 show how students responded to questions about the perceived usefulness (Question 5) and the ease of use of the tutorials (Question 6). When asked to describe their perception about how much the tutorials helped them on the exam (Question 7), 60% of the students felt the tutorials helped them understand or confirm what they needed to do; 17% said that they could not answer this survey question because they did not have enough time to get to the regression question during the exam, while the remaining 23% felt that they would have done just as well without the tutorials. Three percent of the students who happened to be in this last group scored perfectly on the regression question. Finally, every student responded positively when asked if they would like to have more highly interactive tutorials developed for other modeling applications in the course (Question 8).

Table 1: Student perception of the usefulness of the highly interactive tutorials.

<table>
<thead>
<tr>
<th>Results for Question 5 on the survey (Appendix 3)</th>
<th>% of Students that identified this characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helped student understand the Excel mechanics and formula syntax</td>
<td>35%</td>
</tr>
<tr>
<td>Helped student identify the independent and dependent variables</td>
<td>35%</td>
</tr>
<tr>
<td>Helped student interpret the Excel output and forecasting model</td>
<td>42%</td>
</tr>
<tr>
<td>Helped validate the student's thought process and logic</td>
<td>45%</td>
</tr>
<tr>
<td>Did not help the student understand anything more than he or she already knew</td>
<td>10%</td>
</tr>
</tbody>
</table>

Table 2: Student perception of the ease of use of the highly interactive tutorials (where 1 was strongly disagree and 5 was strongly agree with the statement).

<table>
<thead>
<tr>
<th>Results for Question 6 on the survey (Appendix 3)</th>
<th>Average Student Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>The questions and instructions were clear</td>
<td>4.4</td>
</tr>
<tr>
<td>It was easy to enter the Excel responses correctly</td>
<td>4.2</td>
</tr>
<tr>
<td>The interactive format was straightforward once I got the hang of it</td>
<td>4.2</td>
</tr>
<tr>
<td>The tutorial worked correctly for me without any technical problems</td>
<td>4.2</td>
</tr>
<tr>
<td>The tutorial overall was user-friendly</td>
<td>4.3</td>
</tr>
<tr>
<td>The feedback for the different entries/answers was helpful</td>
<td>4.1</td>
</tr>
</tbody>
</table>
6. Discussion

In their paper Haseman et al., (2002) state that "an instructional system that offers greater frequency of interaction and wider range of choices will more actively engage the learner during the session, and to the extent that the system clarifies the link between their choice and the consequent outcome, motivate the learner to perform better." They make the further point that "if designed properly, interactivity in instructional systems may be able to provide support to different types of learners and in each case offer suitable levels of learner control, feedback/reinforcement, flexibility, experimentation, range of choices and practice, all of which can enhance better learner attitude and learning performance." With these types of comments in mind, as OR/MS instructors, we felt that the teaching of spreadsheet modeling skills could usefully be supplemented and/or enhanced by interactive tutorials. Our intention was to move beyond the tutorial that demonstrated or presented a particular procedure or keystroke sequence to achieve a task, and to include student interaction consistent with the 4MAT learning model described earlier in the paper.

6.1. Benefits and advantages

Overall, we would consider our experience in developing the tutorials and using them in class to be positive and pedagogically useful. We see the main benefits as follows:

(a) Instructors can develop a tailor-made personal resource library.

While the creation of teaching support modules in any discipline, not just OR/MS, is not new, this has typically been the purview of professional developers, largely due to the steep learning curve associated with mastering the relevant software packages, such as Macromedia Flash or Adobe Premier, and the time commitments and resources were beyond the typical professor.

We feel that the current generation of screen capture technology has advanced to the point where creating tutorials has an easy learning curve, allowing OR/MS faculty to create a basic tutorial in an hour or so, with the more advanced and interactive tutorials taking up to several more hours depending upon the complexity of the interactivity. This lack of steep learning curve and associated customization provided by the software may be what is required to encourage OR/MS instructors to get involved in these kinds of teaching support activities, since they will see benefits to themselves and their specific way of presenting course material as opposed to just reading about developments in pedagogy research.

Creating our own tutorials gives us the option of customizing each tutorial to be exactly the way each of us wants it to be to supplement our specific approaches to the modeling logic of a given topic. This outweighs the advantage that may be obtained by off-the-shelf modules, even given their more professional looks and features. Updates and modifications can be easily done on an ongoing basis once the software is mastered and the initial development is completed.

(b) Different levels of interactivity can be employed to enhance student learning.

The example tutorials described above were developed to experiment with and demonstrate the different levels of interactivity that are possible. Consistent with Haseman et al. (2002), we feel that higher levels of interactivity encourage students to become active learners by prompting them for their inputs and making them think about the task or problem at hand, i.e., the Extend and Refine activities of the 4MAT model. Students can be prompted for specific inputs such as Excel commands, formulas dialogue box responses as well as broader, more conceptual issues such as identifying the dependent and independent variables as shown in the regression tutorial example.

Another aspect that characterizes the level of interactivity in a learning module is the type and amount of feedback provided. As pointed out in Haseman et al. (2002), feedback is an important mechanism for aiding student learning and four main types of feedback are possible:

(i) Feedback on the Inform and, to an extent, the Practice activities in the 4MAT model, for example, when the student has to step through the Tools - Data Analysis - Regression command. Infinite attempts are allowed for these simple keystrokes and static hints are provided to inform the student until she/he clicks through the correct sequence.
(ii) Feedback on the Practice and Extend activities when the student receives feedback on what they were not doing correctly, either by means of text boxes or more elaborately, by providing the option to review a relevant tutorial in order to guide their learning. Through careful storyboarding and branching options, a sequence of increasingly specific hints can be programmed to hopefully lead students to the correct answer. Unfortunately, with Captivate, these hints will not be context sensitive to the user’s entry as we explain below in the Limitations section.

(iii) Feedback on the Extend and Refine activities through tracking, where Macromedia Captivate monitors the responses the student makes for selected interactive inputs and totals the number of correct entries made. In this way a student gets feedback on the correct number of responses and can see his or her progress and learning improvement on multiple attempts with the interactive tutorial.

(iv) Feedback on the Evaluate and Apply activities via quizzes that can be created to evaluate a student’s comprehension of the main concepts once a tutorial is viewed. Matching, multiple choice, true/false, and fill-in-the-blanks questions can be created and instantly graded when the student completes the tutorial, to provide evaluative feedback. In this way, with multiple attempts at the tutorial and quiz, guided learning will occur.

6.2. Limitations

The limitations or difficulties that we experienced can be considered to fall into three broad categories.

(a) Limitations of the Macromedia Captivate Software:

One main drawback of the software is that entering cell range addresses or formulas in interactive mode has to be done by typing in the appropriate cell references into a text entry box; it is not possible to use the mouse to select a range, or the function wizard to "build" a formula. Unfortunately, this requires the student to focus on the minutiae of a formula (e.g., exact spelling, order of parameters in functions, etc.) rather than how to create it using Excel’s normal features. Depending upon the application, this may or may not be a serious issue. If the purpose of the tutorial is to provide support at the micro level, such as creating a complex formula with absolute and relative references to various cells, then being able to type in the exact formula is of course desirable and necessary. However, built-in Excel functions, especially the more advanced ones, would normally be created using the function wizard with its handy prompts and explanations. On the other hand, students will be expected to interactively choose appropriate Excel commands, such as Tools - Data Analysis - Regression, and that action should be carried out exactly as usual in Excel. Another major drawback is the inability of Captivate to provide context sensitive feedback to an incorrect user entry. This forces the instructor to develop generic messages that must be presented in an increasingly informative order and programmed with different text boxes, thereby increasing the tutorial development time and occasionally resulting in less professional and less helpful tutorials.

(b) Screen capture is not appropriate for all tutorials.

When it is necessary to demonstrate the complex logic or the inner workings of an advanced Excel function, which cannot be captured or recorded, it will be necessary to resort to more sophisticated software such as Flash and build/create the application from scratch. An example of this is in DT-LI1 which could not be created in Captivate since it shows the internal mechanics and calculations of an Excel command which are not displayed on the screen. The learning curve on this kind of effort is significantly more than that required for simple screen capture.

(c) Initial development investment is not trivial.

The time and resource investment required to create interactive tutorials with Macromedia Captivate is much less demanding compared to previously avail-
able software resources as reported in Seal and Przasnyski (2003). However, even though the learning curve is significantly less daunting than that required for Macromedia Flash, the initial development effort is nevertheless not trivial for individuals new to this kind of effort. Thinking through and storyboarding the entire tutorial sequence is an essential first step in the process. If this is not done sufficiently rigorously, the flow and indeed the entire learning content can be lost. Something as simple as wanting to change a cell label in the Excel background after the tutorial has been recorded will require the entire tutorial to be recorded again. Students nowadays expect a professional type product and so a clunky, or confusing, tutorial can easily turn off students and no "value addition" will be perceived. Depending upon the nature of the tutorial being designed, the storyboarding and planning can be a time consuming activity to those unfamiliar with this requirement and process.

The introduction of interactive elements into the tutorial makes the storyboarding requirement that much more crucial than for a linear sequential demonstration tutorial. Creating a sophisticated module in terms of interactivity features will certainly put extra demands on the developer. The consequences of correct and incorrect responses by the student have to be explicitly thought through and a variety of questions need to be answered to manage the potentially highly branching logic. Some of the factors to consider here are: how many attempts should a student have for a particular prompted input? What sequence of hints, or explanations, or tutorials should be used to provide the learning content for the student? How many times should a particular type of feedback be provided? Which set of questions should be included in the final score assessment? Will an interactive question be marked as correct after the first attempt only or will it count if they enter it right on the second attempt?

While recording keystrokes in the tutorials with no interaction is purely mechanical, inserting the interactive components and dealing with any resulting branching will require some more experience with other elements such as working with timeline and layers.

Experience with the software is acquired quickly since it readily allows playback of individual slides and the entire movie, so any changes can be immediately verified and updated as necessary. We would advise that, as part of the initial development effort, tutorials are beta tested by other faculty, or preferably students, if that is practical, in an environment with controlled feedback and evaluation. How much testing should be done depends upon the complexity level (especially the extent of branching logic) of the individual tutorials. We suggest that developing such tutorials may be best done working with one or two faculty, especially if this is a new endeavor, to "share" the initial start up effort.

6.3. Extensions

Finally, we have to keep in perspective that these types of interactive tutorials are not appropriate for supporting the teaching of all OR/MS topics. Nevertheless we feel that they would be potentially beneficial in supporting the instruction of the following types of spreadsheet skills that are necessary as the student transitions from spreadsheet programming to OR/MS modeling:

(a) Structured examples where the student wants to validate his/her thought process for identifying model parameters and variables.

One such example would be a spreadsheet based LP model that has been created for a defined problem and needs to be optimized. Interactive tutorials would help students identify the objective function, the decision variables, and constraint cells in the spreadsheet model and provide support as students attempt to program the various components into Solver. Similarly, students using Crystal Ball with a spreadsheet model that involves uncertainty would find an interactive tutorial useful as they attempt to define the assumption, decision and forecast cells for the problem. Quizzes at the end of both of these applications could assess students’ understanding of the sensitivity analysis and risk analysis results. Interactive tutorials could also be created for the simulation application to help students fit an appropriate probability distribution from Crystal Ball’s gallery to data or estimated parameter descriptions.

(b) Structured examples that emphasize the development of well-designed spreadsheet models before the MS/OR tool is applied, as suggested by Powell (2001).

Exercises that help users practice more advanced Excel tools would fall into this category and could include
tutorials that support students as they compose or edit VBA code to customize an application. Tutorials in this category could also help the user prototype a spreadsheet model based on an influence diagram or patterns recognized from another example. Users can also be asked to apply auditing tools to find logical errors that were intentionally created by an instructor in a spreadsheet model. Exercises that help students identify such errors and rework the model to remove problems such as circular references, redundant cell inputs or nonlinearity would help develop and strengthen user modeling skills.

Tutorials for the first skill category would be easy enough to create once an instructor becomes familiar with Captivate and the storyboarding process. The second proposed category represents a more challenging set of skills, however, that would require a larger amount of creativity and storyboarding effort. The exercises would have to be well thought out to emphasize the particular skill and would most likely involve having to limit the user to guided choices at each stage of the model development (as was illustrated in the data table structure design for the high interactivity tutorial earlier) in order to keep the branching options at a manageable level. The instructor's motivation to create this type of tutorial will be very dependent on the value that the exercise offers the student; if the tutorial addresses a serious shortcoming that the instructor repeatedly sees in student performance, the time and effort required for the development may seem more worthwhile. It is hoped however that as new screen capture software tools continue to emerge and current ones improve, they will help overcome some of the difficulties discussed in this paper so that these applications will become easier to develop and the finished product even more user-friendly.

7. Conclusion

We feel that interactivity has potential to support the teaching of modeling to OR/MS students. Current screen capture software has made this a realistic effort for individual faculty who want to create resources to help students improve their spreadsheet programming skills, but some software limitations and inadequacies nevertheless still remain, in particular for the more abstract and advanced modeling ideas and concepts, which are beyond the scope of the current version of the software. Finally, as OR/MS instructors develop more modules to support their teaching, we recommend that more empirical work needs to be done on systematically evaluating the impact of interactive modules on student learning.

References


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Appendix

Appendix I - Evaluation of Macromedia Captivate

Captivate does not offer all of the features needed to develop a professional level interactive tutorial and this results in some shortcomings of the final tutorial product. For example, Captivate cannot currently record simulations that will allow the user to highlight a range of cells in the spreadsheet as an interactive step, a practice that many users follow in a real spreadsheet session. After the initial simulation recording is finished, any parts that involved the instructor highlighting a range of cells will play back as a demonstration, similar to the playback mode in the low interactivity tutorials. For example, in SLR-HI, after the user reaches the regression dialog box and selects the Y-Range input box, Captivate will highlight the cells for the Y-range automatically instead of letting the student highlight the appropriate cells unless the instructor edits the recorded slides to prevent this. This is a serious problem as identifying the Y variable range is one of the main modeling concepts that the higher interactivity modules are trying to reinforce. The demonstration playback mode also occurs when entries are typed into cells by the instructor during the recording.

To overcome this problem, text entry boxes can be inserted into slides as needed to replace the demonstration playback for both of these situations. For example, in SLR-HI, after the user selects the Y-Range input box, we replaced the highlighting of the Y data cells with a text entry box on the recorded slide. Here, the user is prompted to type the range of cells associated with the Y-variable into the text box. Correct answers are programmed for text entry boxes and if the user successfully types one of the correct choices, the tutorial will proceed to the next screen slide and interaction. If the user does not type a correct choice, feedback for the user will be provided with a static feedback message and a branching option determined by the instructor’s storyboard will be implemented.

Text entry boxes add interactivity into the tutorial by requiring more problem specific input from the users (as opposed to just spreadsheet mechanics) which is helpful as OR/MS instructors start to emphasize modeling concepts. Text entry boxes also provide the instructor with an easy way to implement branching options outlined in the storyboard. For example, Figure 4a storyboards that the user should be given two attempts to correctly type the data cells for the Y-variable. If the user on the first attempt identifies the correct Y variable range, the user will be prompted with an acknowledgement of the successful response before moving on to the next question about the X (independent) variable. If the user does not identify the correct Y variable range on the first attempt, the user will be prompted with a message confirming an error and a static hint to guide them to the correct identification. The user will then have a second attempt to answer the question. If after the second attempt, the user still cannot correctly specify the correct Y variable range, the tutorial will demonstrate the answer by highlighting the cells on the screen before moving on to the question about the X (independent) variable. This type of branching logic is appropriate for medium interactivity tutorials where the instructor is asking the student to recreate an illustrated problem to test if the student has mastered the basic concepts and spreadsheet mechanics.

Figure 4b illustrates a different branching logic for the X-variable question. Here it is storyboarded that the user should be given three attempts to enter the correct X-variable range. If the user does not correctly input the range on the second attempt after a static hint, this part of the tutorial offers the user the choice to branch to the relevant section of the low interactivity tutorial SLR-LI. The user then has the chance to watch how the X-variable range was selected in that tutorial before returning back to the current tutorial and typing the third and final attempt response. Branching to the low interactivity module for reference supports students as they extend spreadsheet modeling concepts to a different problem. By watching the demonstrative tutorial the user is not seeing the answer to the problem on hand, but is seeing how the spreadsheet modeling was approached for a similar example.
If the instructor wants, branching options in Captivate can also be used to force the students to successfully complete an exercise. By programming a text entry box for an infinite number of attempts, the user stays at that particular question and receives the same error message/hint until the question is eventually answered correctly. This is the scenario that is automatically programmed for the single keystroke actions by Captivate in its Simulation recording mode. Some students may become frustrated in this kind of environment, in which case the instructor should provide a way to skip the current screen or even exit the tutorial if desired. Another problem with an infinite number of attempts is the fact that the same incorrect static feedback hint is always provided. As the message is not context sensitive to the error created, this hint may not be of much value. A better approach would be to design a more sophisticated storyboard that branches the student to another text entry box with a different incorrect message if the student does not enter the correct entry on the previous attempt. Unfortunately, this second message would still not be context sensitive to the error that the user is making, which is a major limitation of Captivate.

Incorporating branching options into the storyboard needs to be carefully done and takes some experience. We have learned that you cannot allow too much freedom in the user modeling choices as the number of branching options can easily become unmanageable. For example, consider a multiple regression model where the tutorial needs the user to input the ranges for three different independent variables. If the tutorial is storyboarded to ask for just one input variable at a time then the branching involved would become quite complicated as it would have to keep track of all of the possible correct sequences which the user might enter to identify the three variables. Asking the user to enter ranges for all three independent variables simultaneously will remove this branching nightmare, but will also provide the students with less feedback should they enter only two of the three correct choices: the feedback will not be able to decipher which specific variable has been incorrectly omitted. We have found that in high interactivity tutorials, as the modeling concepts are extended to new or larger problems and emphasized more, it is important to try to keep control of some of the answer options for providing meaningful feedback. Creating four or five buttons that list combinations of choices for the three independent variables in the multiple regression model would allow the user to practice identifying the correct variables while limiting the storyboarding of branching options that needs to be done. If the user selects the button with the correct choice, the tutorial moves on. If the user selects a wrong choice, some feedback is provided about why it is wrong and then the instructor can script what the user should do next.

Finally, Captivate has the capability to add quiz assessment slides to the tutorial after the initial recording is finished. This adds one more high level of interactivity to the learning process as it allows the instructor to include definitions, analysis and interpretation of results, and hypothetical extensions to larger or additional problems without having to storyboard. Quizzes also represent one more type of feedback for the students to help validate their thought processes and mastery of the material. The scores recorded by Captivate at the end of the tutorial will include the performance on the quiz questions, such as in SLR-HI. If desired, the instructor can also select specific text entry boxes storyboarded in the interactive tutorial to count as part of the total score (e.g. DT-HI). Then, if a student enters the text entry box correctly on the first attempt in the tutorial that will be reflected in the final score at the end as well. These final scores should be viewed purely as another source of feedback for the student and not for formal assessment purposes.

Appendix II - Midterm Forecasting Question

The Santa Barbra Zoo would like to forecast quarterly family membership sales for Year 2006. They have collected quarterly sales data for the last 5 years and plotted the data in Chart 1 and Chart 2 of the s06mid1.xls file on your flashdrive. They would like your help in identifying good quarterly forecasts for next year. Please answer the following questions for them.
(3 pts) I. Looking at Charts 1 and 2, describe the behavioral components that exist in this time series.

(4 pts) II. As a first attempt for a forecast model, the zoo created the model on the Exponential Smoothing worksheet of your exam file. Change the value for alpha in cell D2 to identify a good forecast for the zoo. Chart 3 will reflect the forecast that you are creating for different alpha values. What alpha value did you finally decide was the best value? Using your graph and a calculated measure of performance, briefly defend why you like this alpha value.

(7 pts) III. The zoo has collected data about other variables that they believe may influence zoo attendance in general. The zoo would like you to first calculate the trend projection model for this time series on the Trend Projection worksheet of your exam file. Use Excel’s Regression tool to generate the summary output. Fill in the selected boxes below with the numbers shown in your spreadsheet results. Program the forecast for the past quarters in column E. The forecast should now appear in Chart 3. Looking at the graph and a calculated measure of performance, do you think this forecast is better than the exponential smoothing model you identified? Briefly explain why or why not.

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Seasonal Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>8</td>
</tr>
<tr>
<td>Spring</td>
<td>9</td>
</tr>
<tr>
<td>Summer</td>
<td>12</td>
</tr>
<tr>
<td>Fall</td>
<td>11</td>
</tr>
</tbody>
</table>

(6 pts) IV. The data about other variables that the zoo believes may influence attendance is also shown in the Regression worksheet of your exam file. The zoo believes that the price they charge for family membership may have a strong relationship with family membership sales. Perform a regression of family membership sales on membership price and generate the summary output in the Regression worksheet. Fill in the selected boxes below with the numbers shown in your spreadsheet results. The zoo is planning to raise the price of family membership to $70.00 starting next quarter. Calculate a forecast for next quarter in the space below.

(3 pts) V. Of the two forecasts identified in part III and IV, which forecast do you prefer based on its R-square, the trend projection forecast or the regression on membership price forecast? Defend your choice in one sentence.

(3 pts) VI. The zoo wants the final forecast to be off no more than 10% per quarter on average. Do the exponential smoothing or trend projection forecasts achieve this level of accuracy? If so, which one(s)? Defend your answer.

(4 pts) VII. The zoo has estimated the following seasonal indices for this time series. Do you think Seasonal Adjustments using these indices would result in a better forecast? Explain why or why not.

<table>
<thead>
<tr>
<th>The questions and instructions were clear</th>
<th>1—Strongly disagree</th>
<th>2—Somewhat disagree</th>
<th>3—Neutral</th>
<th>4—Somewhat agree</th>
<th>5—Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>It was easy to enter the Excel responses correctly</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>The interactive format was straightforward once I got the hang of it</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>The tutorial worked correctly for me without any technical problems</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>The tutorial overall was user-friendly</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>The feedback for the different errors/answers were helpful</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
Appendix III - Student Survey Form

Student Survey: Forecasting Interactive Tutorials

1. Did you use the Forecasting interactive tutorials posted on Blackboard to study for the exam? Circle your answer.
   a. Yes
   b. No

If you answered yes to question 1, please skip to question 4. If you answered no to question 1, please answer questions 2 and 3 only and turn in your survey.

2. Please identify the reason(s) you did not use the Forecasting interactive tutorials. Circle all answers that apply.
   a. I wanted to but did not have time
   b. I could not access the tutorials successfully through Blackboard
   c. I thought I knew the material well enough and didn't need to
   d. I have watched other snippets posted on Blackboard and did not find them helpful.
   e. Other (please describe briefly):
      ____________________________________________
      ____________________________________________
      ____________________________________________

3. Now that the exam has been completed and you have seen how well you did on the Data Analysis regression forecasting question on the exam, do you think the forecasting interactive tutorials might have improved your score? Circle your answer.
   a. No. I scored very well on the Data Analysis regression forecasting questions.
   b. No. I didn't perform very well on the Data Analysis regression forecasting questions but I don't think it was due to something that the tutorials would have stressed
   c. Yes. They might have helped me understand what I missed. After completing question 3, please turn in your survey.

4. Please identify the number of times that you watched each interactive tutorial. Circle your answer.
   a. Once
   b. Two times
   c. More than two times

5. How would you evaluate the usefulness of the interactive tutorials? Circle all answers that apply.
   a. Helped me understand the Excel mechanics and formula syntax
   b. Helped me identify the independent and dependent variables
   c. Helped me interpret the Excel output and forecasting model
   d. Helped validate my thought process and logic
   e. Did not help me understand anything more than I already knew

6. How would you evaluate the ease of use of the interactive tutorials?
Circle the value that you most agree with in each of the following statements, where

7. Now that the exam has been completed and you have seen how well you did on the Data Analysis regression forecasting questions on the exam, do you think the interactive tutorial helped improve your score?

a. No. I scored well on the Data Analysis regression questions and would have done so without the tutorials.
b. No. I didn't perform well on the Data Analysis regression questions even though I gave it my best try
c. Yes. I think it helped me understand/confirm what to do.
d. I don't know because I did not have enough time to answer the Data Analysis regression questions on the exam.

8. Would you like to see similar interactive tutorials created for other spreadsheet based modeling concepts in the class such as Optimization and Simulation?

a. Yes. They would be potentially helpful
b. No. They don't really help.