Abstract – In an applied introductory Discrete Event Simulation course, students learn the mechanics of developing simulation models and how those models can be used to analyze and improve processes. Often models are developed from word descriptions of manufacturing or service processes. The problems are also intentionally simplified to facilitate students who are being exposed to simulation for the first time and who also have varied backgrounds and experiences. In order for a more complex, real-world process to be assessed, students need a common understanding of or exposure to the process under study. The best method to assist with this leveling of student understanding is to have students spend time viewing the process. However, this is not always practical in a classroom setting. Therefore with the help of several students, I developed a multimedia case study for my Discrete Event Simulation course. The case study is hosted on a frames-based web environment, and includes numerous pictures, drawings, a movie file, and a simulation model with animation. In this paper I discuss the rationale for using a multimedia approach, the advantages of the multimedia approach, and students’ reaction to the multimedia case study.

Keywords: case study, multimedia, simulation.

BACKGROUND

Many undergraduate Industrial Engineering programs offer a course in discrete event simulation. In practice and research, industrial engineers typically use simulation to analyze complex industrial or service systems to identify ways to improve processes by changing manning levels, investing in capital equipment, revising operating policies, etc.

There are two basic approaches to teaching simulation. One approach primarily emphasizes theoretical concepts: the role and proper use of probability and statistics, random variate generation, design of experiments, and statistical interpretation of model performance. The other emphasizes a hands-on approach that typically employs a commercially available simulation tool to develop models, run simulations, and analyze results [Altiok, 2].

While there are proponents for each, or a combination, of these approaches, students taught under these practices frequently exhibit a lack of understanding of how to improve a system after they have learned to construct a model, run simulations, and analyze the output. Possible reasons for this failure include:

- Students have not been exposed to many kinds of industrial and service systems, so their ability to visualize the process and their repertoire of solutions is very limited.
- Students focus mainly on the mechanics of building the simulation model and often believe the problem is solved once the simulation is debugged, verified, and running.
- Students are not provided with adequate exercises or discussions about how to interpret simulation results and what actions to take to improve the system.

This paper focuses on the first bullet point of trying to overcome the limited and varied industrial experiences levels of students. The approach suggested here is a multimedia case study, or learning module, to supplement the

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undergraduate simulation course. The paper begins with a description of a traditional approach to simulation labs, followed by a discussion of the new multimedia approach, and then presents students’ reaction to this approach. This new case study was selected from an actual industrial process that was richly documented with engineering data, diagrams, video, animation, etc. Integrating multimedia presentations of the system and its processes with the study guide gives students a better sense and understanding of the problem being analyzed. A companion paper [Schultz , 3], addresses the second bullet point of how this approach is helping students transition from model building to process improvement.

That there is a critical need for engineering students to achieve the kind and level of understanding addressed by this project is confirmed by the 2003-2004 Accreditation Board for Engineering and Technology (ABET) general criteria for basic level engineering programs, specifically the following parts of Criterion 3 (Program Outcomes and Assessment) [ABET,1]:

> Engineering programs must demonstrate that their graduates have:
> b) an ability to design and conduct experiments, as well as to analyze and interpret data
> e) an ability to identify, formulate, and solve engineering problems
> k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. (ABET, 2002)

**CURRENT IN-CLASS LAB APPROACH**

In-class lab assignments are often used in the hands-on approach for teaching simulation. A popular approach for delivering these lab assignments typically begins with a word description of a manufacturing or service process. The students are then asked to develop a simulation model of this process, and then respond to several questions. The following is an actual problem description for an in-class lab.

**Simulation Problem:** Kits of two types of PCBs (Printed Circuit Boards), a memory board and a processor board, already automatically populated with axial components, surface mounted devices, and various chips, are sent to a PCB assembly and test facility. The memory boards arrive in batches of 10 and are scheduled to arrive every 30 minutes. The processor boards arrive in batches of 5 with an exponential inter-arrival time distribution of 20 minutes. The remaining components of these boards (the one that are not possible to insert automatically) are manually inserted by 2 different assembly lines, each staffed with three operators. The insertion time for memory boards is Triangular with mode of 6 and a minimum of 4 and a maximum of 10 minutes. The insertion time for the processor boards is also Triangular with mode of 7 and a minimum of 5 and a maximum of 11 minutes. The manual assembly is followed by a wave solder, taking a constant 1.5 minutes. The solder boards are then visually inspected by one of three operators who check for solder quality as well as missing or wrong components. 5% of memory boards and 7% of processor boards fail inspection. The inspection time follows a lognormal distribution with mean of 4 and standard deviation of 1 minute.

When reading through this description, students develop a mental image of this process. However, if a student has never seen a wave solder machine, what do they picture? Or if a student has never worked in a manufacturing facility, or have seen how components are inserted into a PCB board, how do they visualize this process? The student may be able to develop a simulation model without a good feel or picture of the process, and they may be able to do analysis and determine the bottleneck of the process. However they would likely have difficulty in coming up with suggestions for improvements to the process.

**Observations**

Based on several years of experience with this type lab approach, I have made the following general observations:

- most students can develop the basic simulation model for the described process;
- most students can answer questions and generate statistics about the performance of the process using the simulation model;
− over-simplification of the process is sometimes necessary when relying on just word descriptions;
− with no mental image or experience base to draw on, students develop different mental images of the described process;
− students with little industrial experience are typically at a disadvantage when asked to suggest process improvements.

NEW MULTIMEDIA APPROACH

In order to help students better visualize the process being studied a new multimedia approach has been developed that builds on the current lab approach. This section begins with a rationale for this new approach, followed by a description of the approach, and concludes with advantages and disadvantages of the approach.

Rationale

A crucial point when teaching simulation is to emphasize that simulation is just a tool. The real goal of a simulation study is process improvement. Therefore learning objectives for the simulation student should include:

− what simulation is;
− reasons to simulate;
− how to use the simulation tool to model a process;
− and, how to apply this tool to improve the process.

The last learning objective of process improvement can and is sometimes overlooked. This learning objective also is the most challenging to present as suggested by the observations stated above.

Several approaches can be used when addressing the process improvement learning objective. One approach is to model and analyze a process which all students are familiar with. For example, one can model the checkout lanes at a retail store, or the ordering process at a fast food restaurant. Or, a simplified version of an actual manufacturing process can be used. The first approach overcomes the familiarity issue and “levels the playing field”. While the second approach introduces applications more aligned to what the student may encounter in their future profession.

But to truly begin addressing process improvement, students need to be challenged with a realistic real-world simulation project. To provide the student with this real-world experience, one must overcome the problems of the varied levels of student industrial experience and the inclination to oversimplify the real process. The best way to achieve this is to have the student model and improve a real manufacturing process which they can observe and spend time with. However, the logistics of having 30 students view and spend time with a real manufacturing process is not easily accomplished. This issue led to the development of a multimedia case study approach.

The Approach

The case study consists of three primary multimedia tools. These tools are hypertext markup language web pages, streaming video, and discrete event simulation models.

Hypertext Web Pages:

The web pages present the learning module and case study instructional material. The web pages also provide a structure for the student. The first of several web pages is a brief introduction that describes the purpose of the learning module and instructions on how to navigate through the case study. All web pages are similar in format. Each page has a common set of hyperlinks in the left-hand column and a unique set of information or instructions in the body.

In addition to the introductory web page, the learning module includes the following case study instructional web pages:
Problem Background - provides a brief description of the production environment, the products, and the general production process. The description includes pictures of the products and drawings of each product’s parts and subcomponents.

Process Description – provides a detailed description of the production system and process steps. The description includes an overhead engineering drawing to help students visualize the actual process.

Problem Statement – describes management concerns/issues regarding the current system.

Process Data – provides details of relevant process data such as processing time distributions, setup time distributions, number of available resources, shift schedules, rework percentages, product routing data, etc.

Production Schedule – describes the production schedule of the system.

Student Assignment – describes the students’ assignment with links to all proposed improvement scenarios. Each scenario describes a general process improvement idea and includes data relevant to the idea including cost assumptions and the impact of this improvement on process data. While these are the proposed ideas, students are not limited to this set of improvement scenarios.

Streaming Video:

As the saying goes, “a picture is worth a thousand words.” One of the key features of this learning module is a short streaming video of the process. I emphasize in my class that the only way to really understand a process is by spending time with it, watching and observing. The video allows the students to “virtually” visit the process under study.

The streaming video is a one-minute clip of the system in operation. The video in effect shows all the steps in the production process. The purpose of the video is to provide the students with an actual view of the process. The video is not meant to be used to collect data. All pertinent data are provided either in the case study instructional web pages, the base simulation model or the proposed process improvement scenarios. Figures 1 and 2 are snapshots of the streaming video.

Figure 1 – Door Panel Glue and Assembly Operation
Simulation Model:
The third tool of the learning module is the base simulation model. Recall that an emphasis of this multimedia learning module is not only system design but also process improvement. Therefore, a simulation model of the base (current) system has been provided for three reasons. The base model:

− shifts a student’s focus from building the model to using the model for process improvement;
− provides the student with a new perspective on learning how to embellish an existing model; and
− introduces new simulation constructs and modeling strategies, which the student will need to investigate before they can fully understand all facets of the model.

The students are expected to review the web pages describing the system and problem, view the video footage, and complete each of the assignment scenarios. To complete a scenario, the students must modify the base simulation model, perform a series of experiments, and report the results. The students then make final process improvement recommendations, justifying those recommendations.

The case study website can be accessed at: http://faculty.mercer.edu/schultz_sr/courses/ise403/casestudy.

Advantages
The advantages of this multimedia lab approach for simulation include:

− it “brings” the factory to student and helps level their understanding;
− it provides a wealth of information (part and process drawings, process data, simulation model, photos, video, etc…) about the process under study;
− it is portable to other learning institutions.
Disadvantages

Some disadvantages of this multimedia approach include:

- the labs are time consuming to develop; and
- companies are reluctant to allow video footage of their operations.

Early Feedback

This multimedia approach was first used in the Spring 2005 semester. The students were mostly Juniors, with relatively little manufacturing experience (most of our students begin summer interns between their Junior and Senior years). Intentionally, the case study was delivered by the instructor giving a brief introduction and then leaving the room. The purpose of this approach was to determine if the lab could be delivered with no additional help from the instructor.

Upon completion of the multimedia case study, students were asked to take a written survey. A total of 16 students completed the survey. A partial listing of questions from the multimedia section and average scores based on a scale of 1 to 5 are given in Table 1.

Table 1: Partial List of Survey Questions and Associated Student Responses

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>Avg Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Were the process descriptions helpful in understanding the process?</td>
<td>4.1250</td>
</tr>
<tr>
<td>Were the layout drawings helpful in understanding the process?</td>
<td>4.0625</td>
</tr>
<tr>
<td>Were the product drawings helpful in understanding the process?</td>
<td>3.8125</td>
</tr>
<tr>
<td>Was the video helpful?</td>
<td>4.0625</td>
</tr>
</tbody>
</table>

In the modeling section of the survey, the most telling question is “Were you able to understand the model’s logic?” Table 2 summarizes the responses by percentage of students. It can be seen that a modest 43% of the students felt that they could at least understand most of the model logic by week 10 of the course.

Table 2: Student Response Percentages for the Question “Were you able to understand the model’s logic?”

<table>
<thead>
<tr>
<th>Response</th>
<th>% of Student Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>18.75</td>
</tr>
<tr>
<td>Mostly</td>
<td>25.00</td>
</tr>
<tr>
<td>Some</td>
<td>37.50</td>
</tr>
<tr>
<td>No</td>
<td>18.75</td>
</tr>
</tbody>
</table>

In the process improvement section of the survey, 100% of the students indicated that the case study helped enhance their understanding of how simulation could be used as a process improvement tool. The students were also asked what would help improve their ability to generate process improvement ideas. Most responded that additional case studies of “real-life” problems using this multimedia approach would help. In addition, the students indicated that more discussion in class about process improvement ideas would strengthen this ability. A final question on the survey was “Should the instructor develop additional multimedia case studies?” All students indicated “Yes.”
Some general conclusions that can be made from the survey questions and comments are:

- The simulation modeling logic is more advanced than the average student was ready for at that stage (week 10) in the course. To address this, we could consider presenting this case study later in the semester, or perhaps provide a case requiring less complex model logic;
- Having the instructor in the classroom during the case study would have greatly helped the class overcome some initial hurdles in the model logic;
- The multimedia approach was well-received, and additional case studies are requested;
- Some students were comfortable with process improvement before the case study, but the case study definitely helped; and
- Students requested additional real-world case studies to help improve their understanding and experience with process improvement.

**PROPOSED CHANGES**

While the pilot was generally successful in the goal of helping students become exposed to a real-world process improvement simulation study, I plan to make several changes during the next delivery of the case study. These changes include:

- Stay in the classroom to address modeling logic questions. The complex logic hindered some students from focusing on process improvement, or being able to implement their process improvement ideas.
- Deliver the module later in the semester (week 12 or 13). With a couple of more weeks of modeling practice, the students will be better prepared to undertake the case study.

A longer term goal is to find another company willing to participate by allowing videos to be taken of their manufacturing processes, hopefully filming a process that requires less complex modeling logic.

**SUMMARY AND CONCLUSIONS**

Discrete event simulation is taught in many undergraduate Industrial Engineering programs throughout the world. Students typically gain a general understanding of the theory behind simulation and the mechanics for developing a model and analyzing results. This paper presents a means to take simulation instruction one step further. The approach is a novel multimedia case-based learning module that helps students gain a better understanding of the process under study. The modules consist of three primary components: (1) a web-based case study guide, (2) actual information about the real-world industrial system described in the case study, and (3) a simulation model of the base system. The actual information included uses multiple representations and views of the system and its process steps (e.g., engineering drawings, video footage of the system in operation, etc.) in a case study format, an approach that has not been explored previously in teaching industrial simulation.

The multimedia learning module teaching approach is pilot tested and the preliminary results are quite promising. This new approach of embedding real-world information and data of the actual process in a case study format was well-received by the students. Furthermore, based on the in-class feedback and survey responses, the students benefited from using the learning modules in that the modules helped them readily “see” the process and helped improve their ability to generate creative process improvement strategies.

The next steps are to use the general conclusions drawn from the student comments and from future course offerings to improve the components of the multimedia learning modules to increase their effectiveness and educational benefit.

**REFERENCES**


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