Further improvement of a course on discrete-event modeling and simulation: a follow up study

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Abstract

Discrete-event modeling and simulation plays a key role in design and optimization of production systems as such systems become increasingly complex. Engineering technology students should be familiar with the simulation techniques in their field of study and in addition, they should be able to design and run simulation experiments. The latter can be achieved by defining either individual or group projects wherein students develop solutions to the problem using modeling and simulation methods.

In an initial investigation, the author examined the results of bringing real-world projects into a course on discrete-event modeling and simulation. The course was, and still is, a cross-listed course (e.g., undergraduate and graduate courses are combined into one course). Based on the results, the author modified the group project requirements to address the issues observed in the initial investigation. The modified syllabus has been used twice and it is the author's belief that this modified approach has helped students more effectively.

In this article the course contents and requirements such as assignments, and group projects are described, followed by a discussion on the results of using real world projects in the course. Modifications and changes done based on the results of using the real world projects, as well as the observed improvement in terms of students' performance in the group project is also, discussed.

Introduction

Manufacturing simulation (IET 369) is a senior-level undergraduate course within the curriculum of Industrial Engineering Technology (IET) at Indiana University-Purdue University Fort Wayne (IPFW). The main purpose of the course is to introduce discrete-event modeling and simulation to IET students with the following objectives:

- Learn the purpose and usage of modeling and simulation, model building, model verification, and result interpretation.
- Understand and apply statistics and probability as is used in a simulation experiment.
- Use ARENA as a simulation tool to model and simulate manufacturing systems.
- Be able to complete a manufacturing system simulation project from beginning to end.

There is also a graduate-level course, Simulation Modeling (TECH 569), that is being cross-listed with IET 369 with similar objectives but higher expectation and extra activities to be suitable for a graduate-level course.

The topics that are discussed in the course are shown in Table 1.

Table 1. The main topics discussed in both IET 369 and TECH 569

Topic	Duration (approximation)
– Discrete-Event Modeling and Simulation – Statistics and Probability	3 weeks
– Random numbers – Introduction to ARENA	2 weeks
– Model Testing (Verification and Validation) – Input Analysis – Model Goodness	6 weeks
– Case studies – Group project finalization	3 weeks

Course requirements

Aside from typical requirements such as assignments, exams, and attendance, the following requirements were of especial interest:

<u>Textbook</u>

Originally (fall 2011 and 2012), the author used Altionk and Melamed's Simulation modeling and analysis with ARENA [1] for both IET 369 and TECH 569. The textbook has a good treatment on how to use ARENA in various situations ranging from manufacturing to healthcare systems. The exercises are relevant and clear. However, the textbook could include more details on mathematical treatments of the subject such as probability distributions and statistical inferences.

The author also used Banks, Banks, Carson II, Nelson, and Nicol's Discrete-event systems simulation [2] in an attempt to teach the fundamentals of modeling and simulation in more depth. This textbook treats the fundamentals extensively. It does not specifically discuss the application of a software package, though a chapter is dedicated to describe various software packages. Other textbooks ([3], [4], and [5]) were reviewed for the purpose of the courses; however, some of these textbooks ([4] and [5]) seem to be more adequate for engineering disciplines than technology (e.g., the mathematical treatment is more rigorous). In the case of [3], the textbook is suitable for teaching ARENA in details and, though it includes various exercises at the end of each chapter, the fundamentals of modeling and simulation were explained briefly.

<u>Software</u>
There are several software packages dedicated to discrete-event modeling and simulation such as ARENA, Simio, ProModel, FlexSim, to name a few. A quick review of these packages indicated

that some of the packages are more extensive in terms of the scope of their usage and targeted industries, knowledge of programming in specific language, and as such. ARENA, on the other hand, seems to focus less on the programming details, though one could still manipulate the codes to customize a model. In addition, ARENA is a high-level visual software that allows users to choose appropriate model elements easily. This would make modeling less intimidating for beginners. Therefore, the author believes that ARENA is more adequate to be used in these courses.

The software packages are offered under various licenses including commercial and academic (some may have different name of even category such as research license). Typically, the academic license has limited capabilities (e.g., one cannot build models whose number of objects exceeds certain limit). However, to model and solve the exercises in [1], the academic license is sufficient. The issue that may arise is with regard to group projects which will be discussed next.

<u>Group projects</u>

The main purpose of the group project was to provide an opportunity for students to work on a project with emphasis on a real world manufacturing situation. The instructor would group students randomly and each group was to come up with a topic. Once approved, the groups would proceed to complete the project. The group project report should include the following:

- Project Introduction (statement of the problem, objectives, etc.)
- Description of the methodology
- Details on how the model was built, how data were collected, and also, simulation details.
- The findings and the relevant discussion
- Suggestions and recommendation for the management

The instructor modified the group project requirements in the following year to introduce two real-world projects with the goal of [6]:

- Providing students with an opportunity to apply the lessons learned in the real world.
- Helping local industries with their manufacturing challenges by promoting community engagement and mutual collaboration.

Each group selected one project and completed it through three phases, shown in Figure 1. Some of the issue arose with the real world project were as follows (a more detailed description can be found in [6]):

1. The impact on the course requirements and assessment. The instructor had planned on giving a total number of 10 assignments. However, since both of the groups needed extra time to complete the projects, he had to changes the total number of assignments.
2. The projects requirements and scope may change over the period of time by the company. This would have a negative impact on the goals and timetable that have already been established.
3. Time management could be an issue. Students needed to visit the company several times, outside of class time. Finding a good time to meet with the company's key personnel involved in the project was not always possible and it delayed meeting the project goals.

4. Validation. In order to validate the results produced by the simulation experiment one should either have real world data from the process or conduct statistical analysis to validate the results. However, the lack of reliable data that necessary to validate the model could be a serious obstacle. Statistical validation could be performed provided that basic reliable data (such as cycle time) are still available.

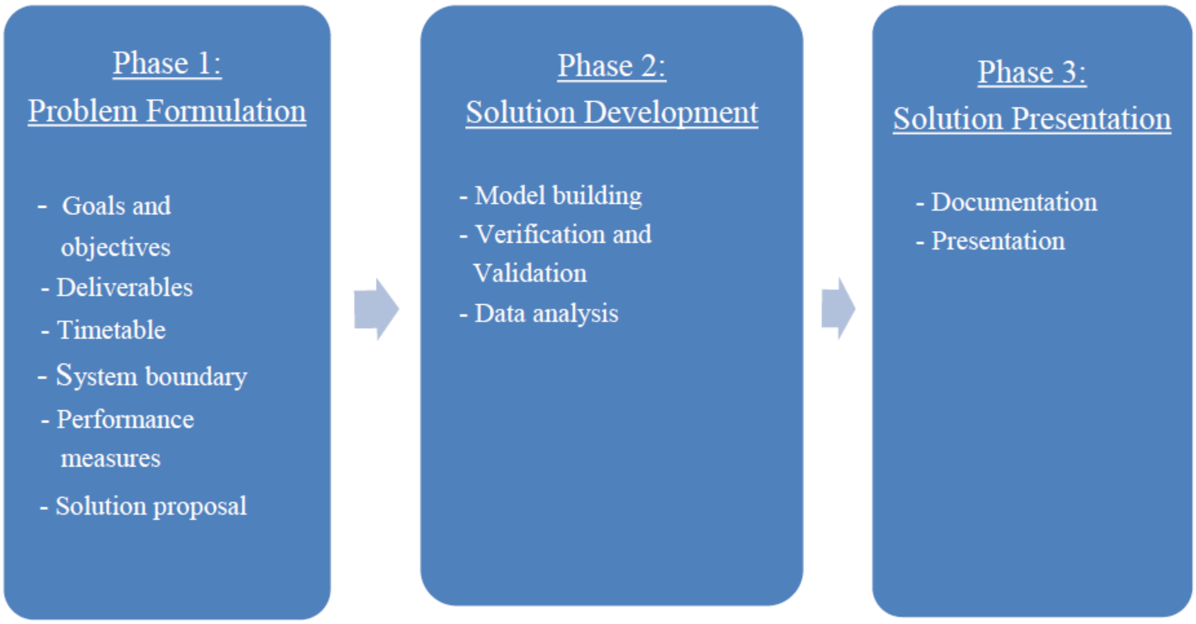

Figure 1. Group project phases ([6])

Therefore, the author decided to make another modification to introduce real-world projects that had been completed before. This would address the issues mentioned above and still address the author's concern about using real-world example. The author used a real world project that had been already completed and introduced it to the students. The students were grouped in two groups of 2 and 3 students, both were tasked with conducting the simulation experiment to address the project's questions which was to determine whether the current capacity of a workstation is capable of catching up when the initial order would be doubled or tripled.

The groups would need to follow the following steps to complete the project:

- Problem statement (i.e., objectives, scope of the problem, questions to be addressed, a time table to complete the project)
- Data needed, identification of variables and parameters, their types,
- Data collection
- Model construction
- Verification and Validation (V&V)
- Conduct the experiment
- Output analysis
- Final recommendation (i.e., group presentation and project report)

The groups completed the project in a timely manner and presented the results in the class which was interesting in particular, because they came up with two different solutions to address the issues. It was also educational for the groups to compare and contrast their findings with one another to learn what they could have included in their analyses, how to build the model, etc. The following rubrics were used to grade the projects:

Elements			**Percentage**
Peer evaluation			30%
Presentation Evaluation	Students evaluation	20%	30%
	Instructor evaluation	10%	
Project Report	Contents (simulation steps, accuracy, etc.)	15%	40%
	Detailed analysis, discussions, and recommendations	15%	
	Appropriate graphs, tables, etc.	5%	
	Report structure, grammar, format	5%	
Total			100%

The instructor used the research version of the software to insure that students would not run into limits posed by the education license. However, as mentioned earlier, it could be a problem, aside from the fact that one would violate the license agreement.

Students evaluations indicated that the majority of them found the group project useful and educational, particularly because the projects were real-world ones. The course evaluations of the semester during which the two projects had been used indicated that some of the students were concerned with time management and changing the project's scope, as were mentioned before. However, after the latest modification (i.e., bringing a project that was already completed) resolved these concerns. Table 2 includes the most recent course evaluation, when the course was modified (the results of fall 2013 survey were not available).

Table 2. Students' responses to course evaluation (1: poor, 4: excellent).

Questions	**Semester**		
	Fall 2011 (Enrollment: 5)	Fall 2012 (Enrollment: 2)	Fall 2014 (Enrollment: 3)
The class contents	2.0	2.5	3.33
The textbook	1.4	1.5	2.0
The relevance of Assignments/Homework to the course goals	2	3.5	3.33
The adequacy of exams, reports, etc. in measuring student's understanding of the subject	2.8	2.5	3.33
The course overall	2.0	2.5	3.33

Conclusion

A description of the changes made to further modify a course on manufacturing modeling and simulation was presented. Based on the instructor's experience and feedback received he believes that changing the group project scope and requirements were the most important aspect of his attempt to improve the course, although the issue of finding a more appropriate textbook remain partially addressed. One solution would be to develop lectures on the fundamentals of modeling and simulation and use [1] to teach the software. This will be investigated in future.

Reference

[1] T. Altiok, and B. Melamed (2007). *Simulation modeling and analysis with ARENA*. Burlington, MA: Academic Press.

[2] J. Banks, J. S. Carson II, B. L. Nelson, and D. M. Nicol (2010). *Discrete-event systems simulation* (5th Ed.). Upper Saddle River, NJ: Prentice Hall.

[3] W. D. Kelton, R. P. Sadowski, and D. T. Sturrock (2007). *Simulation with ARENA* (4th Ed.). New York, NY: McGraw-Hill.

[4] A. M. Law (2007). *Simulation modeling and analysis* (4th Ed.). New York, NY: McGraw-Hill.

[5] S. M. Ross (2013). *Simulation* (5th Ed.). San Diego, CA: Academic Press.

[6] A. Alavizadeh (2013). "Industry Engagement in a Manufacturing Simulation Course". *American Society for Engineering Education (ASEE) Conference,* Atlanta, GA.