Strategies to Improve Student Engagement in a Facilities Planning Course through Hands-on Learning Activities

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Abstract

The continuously increasing competition in the job-market results in higher expectations from engineering and technology graduates. To stay competitive, engineering and technology students need to learn the latest software used in their associated fields as well as to understand relevant modeling and simulation frameworks. To provide students a better learning experience discrete-event modeling software based hands-on learning examples are developed and implemented for the junior level Facilities Planning course. This paper shares examples of the hands-on learning activities that are incorporated into the Facilities Planning course.

Introduction

According to the International Facility Management Association (IFMA)'s Profiles 2011 Salary and Demographics Research Report, the average facility manager is "*personally responsible for the entire facility space, managing multiple functions, including operations, maintenance and energy management*", "*responsible for managing supervisors, with a staff of one to five employees*", and "*manages more than one million square feet, predominantly office space*" [1]. This summary of responsibilities suggests that facility management is a multi-faceted discipline that involves management of physical space, people and time. Therefore, the facility management role draws from many topics including decision making, information management, organizational and service management [2]. After a systematic review of 83 journal articles, Nenonen et al.[3] identified management, engineering (including informatics), and architecture as the top three disciplines mostly applied to Facilities Management. Since the field involves issues that cross disciplinary boundaries, the problems facility management studies are involved with are usually complex, and they often require computational approaches.

One stream of research that involves computers in the area looks at how various system implementations can accomplish specific facility management tasks. For example, Gerrtis et al. [4] examined the pick-up and docking of semi-trailers using a Multi-Agent System (MAS). In another study, Gootzen et al. [5] examined the full roaming shuttle system in automated storage and retrieval systems.

Another stream in the facilities management research aims to solve optimization and scheduling problems through simulation modeling. For example, Baddock et al. [6] presented a case study for a high mix, low volume manufacturing shop for printed circuit boards, and incorporated the use of a simulation model for discrete event modeling. Rajamanickam et al. [7] studied the truck congestion problem and employed VISSIM, a micro-simulation software, to solve the problem. Misola et al. [8] presented a genetic algorithm to solve the facility layout optimization problem to minimize the material handling cost of the system. Seliger et al. [9] showed a discrete-event simulation model that is developed to analyze the performance of the remanufacturing facility for mobile phone. Kim et al. [10] proposed a simulation-based scheduling system for machine shop operations that reduces the cost of energy, where a case study of a manufacturing facility with 29 CNC machines was examined. Baines et al. [11] examined the human component of automotive manufacturing systems and aimed to increase the reliability of simulation prediction models via discrete event simulation models.

With the current advances in the field, it is essential for the faculty who are teaching facilities related courses to incorporate the methods, tools, and techniques mentioned above to keep curricula relevant and up-to-date. Moreover, using computer-based technologies (particularly simulations) have added benefits for students' learning experience. Rutten [12] examined the learning effects of incorporating simulation in traditional classroom settings, and proposed computer simulations can serve as enhancement or replacement to conventional instruction. Hennessy et al. [13] concluded that instructors prefer computer-based technologies since they allow not only to replicate the real experiments, but also to explore "what-if" scenarios. To that end, many scholars investigated the use of simulation-based instructional materials. For example, Montevechi et al. [14] examined the use of discrete event simulation and how it can be used to increase students' understanding of the real systems in conceptual models, where Lego Mindstorms' robot application was used as an example for the project. Skoogh et al. [8] examined ways to include simulation as part of learning objectives by including objectives to learn discrete event simulation.

This paper aims to propose a set of hands-on learning activities to enhance the learning experience and help students gain expertise in the subject matter. We believe the hands-on aspect of the learning experience ensures students' understanding and comprehension of the subject while providing them real-life-based examples and exercises that simulate industrial settings.

Course Overview

Facilities Planning course is a required course for Bachelor of Science in Facility Management Technology – Industrial Technology program offered in the Mechanical Engineering Technology Department at Farmingdale State College, State University of New York. Mechanical Engineering Technology BS degree and Manufacturing Engineering Technology BS degree students can take the Facilities Planning course as a technical elective.

Facilities Planning course covers the concepts and techniques to generate facility plans. Students learn the requirements and planning of people, equipment, space and material in facilities as well as evaluation, preparation, and implementation of facility plans. The course is offered in a traditional setting where the theory is covered through lecture slides, lecture notes accompanied by the course textbook. As the course textbook, Facilities Planning by Tompkins, White, Bozer and Tanchoco, 4th Edition [15] is used.

Hands-on Learning Activities

As a part of the Facilities Planning course, a set of hands-on learning activities are developed and implemented into the course. These hands-on learning activities are introduced to students in a tutorial style, and completed during the class time. ARENA by Rockwell Automation software is used as the hands-on learning software platform. Arena [16] is a discrete event simulation software and users can use the existing templates and library to develop their models, assign values, variables and other relevant data. The simulation model provides an opportunity for students to see how systems/processes/facilities run while presenting computational outputs to help students understand and analyze the characteristics of processes. Outputs from the simulation can be used as input to develop appropriate plans for various facilities.

The Facilities Planning course do not have a laboratory component, however, the course was held in a classroom where students had access to a computer during the lecture. Hands-on learning activities are approximately 20-30 minutes long depending on the example and all activities follow the same steps:

- ***(i)*** Introduction to the hands-on learning activity: An overview of the activity along with learning outcomes for the in-class hands-on learning activity is discussed.
- ***(ii)*** Introduction to the ARENA Software: An overview of which templates, modules will be used, their functionalities and discussion on how the facility (process) will be modeled.
- ***(iii)*** Building the Facility Model: A step-by-step approach to develop the model for the facility. Students build the model along with the course instructor.
- ***(iv)*** Running the Simulation: Run parameters such as run time, number of repetitions... are discussed. Simulation successfully completed.
- ***(v)*** Reviewing the Results: Once the simulation run is completed, ARENA software generates a report providing a detailed look at the outcomes. A discussion on which outcomes are of interest for further analysis is completed.
- ***(vi)*** Analysis and Planning: The outcomes are analyzed and planning of the facility is discussed. If needed, future simulations and analysis recommended.

As a part of the Facilities Planning course, a variety of facilities are examined; two hands-on learning examples of manufacturing facilities are shared in this study:

Hands-on Learning Example 1: Manufacturing Facility

In this hands-on learning activity, students are provided with a two-stage manufacturing process example where raw materials arrive to the system then go through manufacturing operation 1 and manufacturing operation 2, respectively. Upon completion of the manufacturing operations, the completed parts leave the facility. At this stage, parts may be going to another department for additional operations such as surface finishing, painting… or if all the manufacturing operations are completed, they may be going to the packaging and shipping department.

At the modeling stage, an in-class discussion is carried out to identify what kind of information is needed (as input) to truthfully model the system. As an example: information on how often raw materials arrive, how long it takes for a manufacturing operation to process a part, and how long the facility works everyday (1 shift vs. 2 shifts, or, 24 hours) are identified. The next step is identification of the ARENA template to be used for the simulation. For the Manufacturing Facility example, ARENA's Basic Process template is used. Basic process template has a set of modules available for users to incorporate into their designs. For this in-class example, three different modules are used: "Create", "Process", and "Dispose", as shown in Figure 1a.

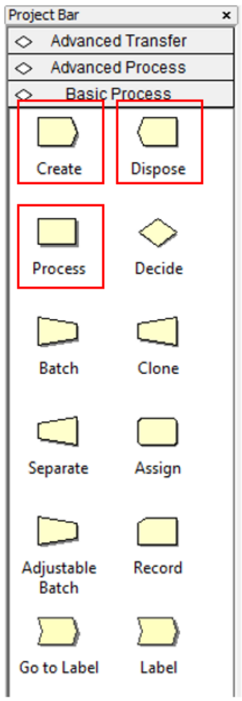


Figure 1a. ARENA Basic Process Template (Create, Process, Dispose Modules)

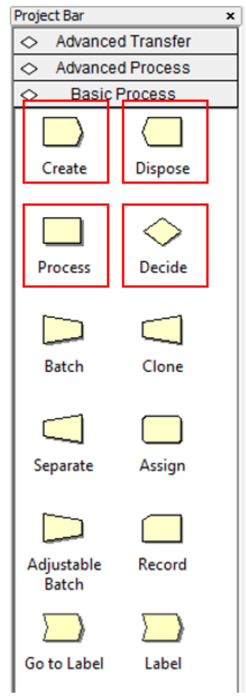


Figure 1b. ARENA Basic Process Template (Create, Process, Decide, Dispose Modules)

Create module is the entry point or starting point of the manufacturing facility, this is where parts arrive to the system (they are created). In a manufacturing facility, the arriving parts may be raw materials or in-progress parts that need additional manufacturing operations. The Process module is where the manufacturing operation happens. And, the Dispose module is where the parts leave they system for shipping or for another facility for additional operations.

The in-class hands-on manufacturing facility example is modeled with deterministic data and shown in Figure 2. The manufacturing facility have parts arriving at a constant speed of 10 parts arrival every hour. Manufacturing operations 1 and 2 processes the parts at a constant speed of 0.3 hours and 0.4 hours per part, respectively. The dispose module doesn't have a time component attached, parts reach the Dispose module, leave the manufacturing facility. The simulation length (simulation run time) for the manufacturing facility is set to 320 hours (8 hours/shift * 2 shifts/day * 20 days/month) to simulate the facility for a month.

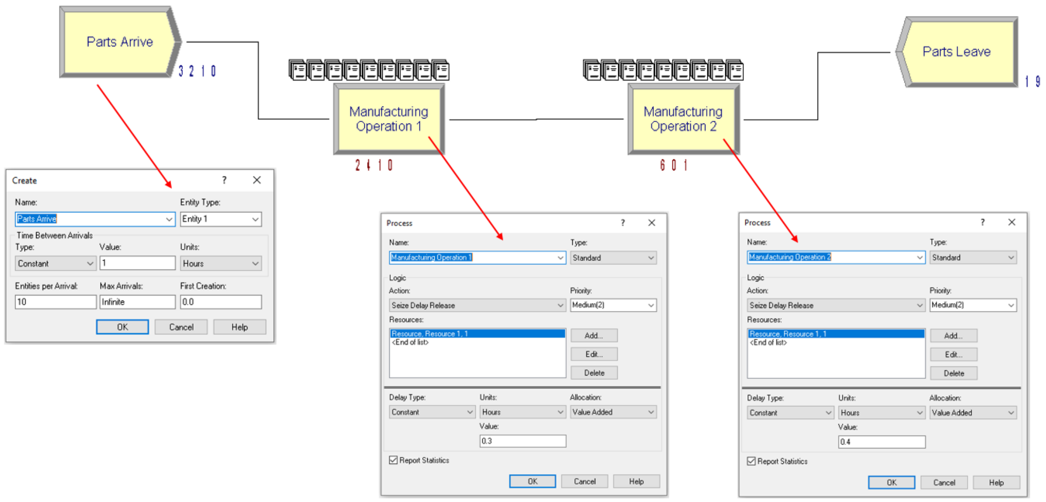


Figure 2. Manufacturing Facility ARENA Model

Once all the input is completed, simulation is run to examine how many parts arrived to the system, how many parts passed (completed) manufacturing operations 1 and 2, and how many parts left the system. For the manufacturing facility, 3210 raw material (raw parts) arrived to the system, 2410 parts passed Manufacturing Operation 1, 601 parts passed Manufacturing Operation 2, and finally 199 parts left the system. The goal of any manufacturing operation is to complete as many good parts as possible. As it can be seen from Figure 2, queues formed in both manufacturing operations. Queue Detail Summary that shows the waiting times and number of parts waiting for both manufacturing operations can be seen in Figure 3. Knowing queue outcome helps facility planners design spaces and operations accordingly and provides an opportunity for planners to make appropriate recommendations.

Replication 1 Start Time: 0.00 Stop Time: 320.00 Time Units: Hours

Queue Detail Summary

Time

	Waiting Time
Manufacturing Operation 1.Queue	120.19
Manufacturing Operation 2.Queue	120.60

Other

	Number Waiting
Manufacturing Operation 1.Queue	1204.22
Manufacturing Operation 2.Queue	300.20

Figure 3. Queue Detail Summary for Manufacturing Facility Example

Hands-on Learning Example 2: Manufacturing Facility with Quality Control

In the second hands-on learning activity, a Manufacturing Facility with Quality Control component is examined. In this example, raw parts arrive to the system, and go through

Manufacturing Operation 1, and upon completion of the initial manufacturing operation, parts go to Quality Control station. At the Quality Control station, a variety of characteristics can be checked, such as: dimensions, weight, appearance, function… to see if the parts meet the requirements. If parts meet the requirements, no further manufacturing operation is needed, and parts leave the system. If parts do not meet the requirements, they are sent to Manufacturing Operation 2 for additional operations. Parts that leave the Manufacturing Operation 2 leave the system. In this hands-on example, it is assumed that parts that fail the Quality Control first time meet quality standards upon completion of Manufacturing Operation 2. This in-class example also uses Basic Process Template with four different modules: "Create", "Process", "Decide" and "Dispose", shown in Figure 1b.

The manufacturing facility have parts arriving at a constant speed of 10 parts every hour. Manufacturing operation 1 processes parts at a constant speed of 0.3 hours per part. Following the Manufacturing Operation 1, parts arrive to the Quality Control Station (Decide Module). The Decide module's 2-way by Chance option is used; where 95% of the outcome is "True" meaning 95% of the parts that arrive to the Quality Control module pass the Quality Control. The remaining 5% is send to Manufacturing Operation 2 for further processing. After the Quality Control station, parts that need additional work go to Manufacturing Operation 2, where parts are processed at 0.1 hours per part, as shown in Figure 4.

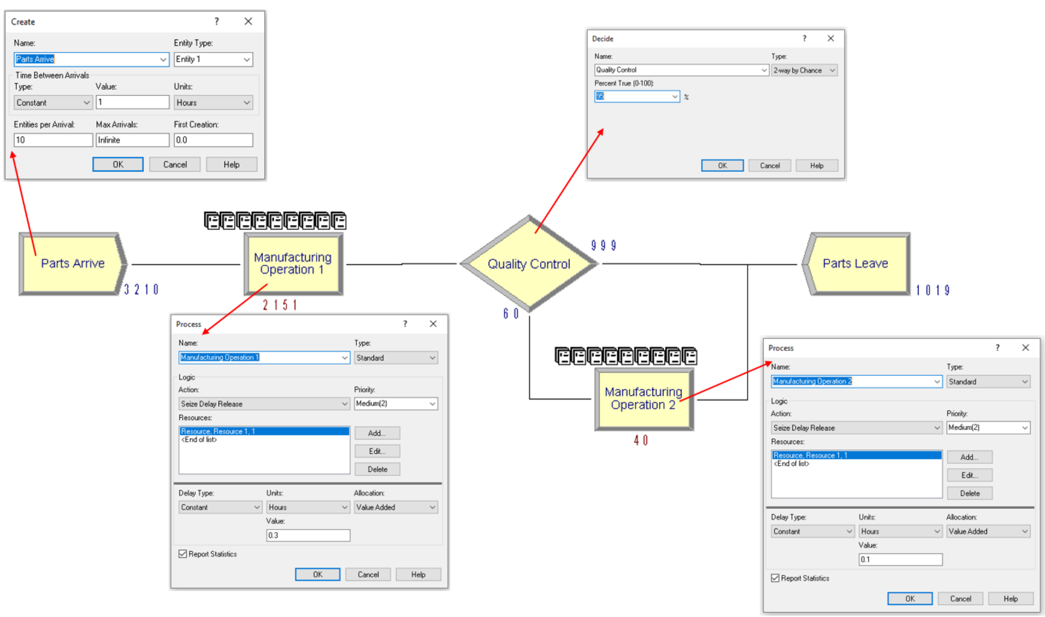
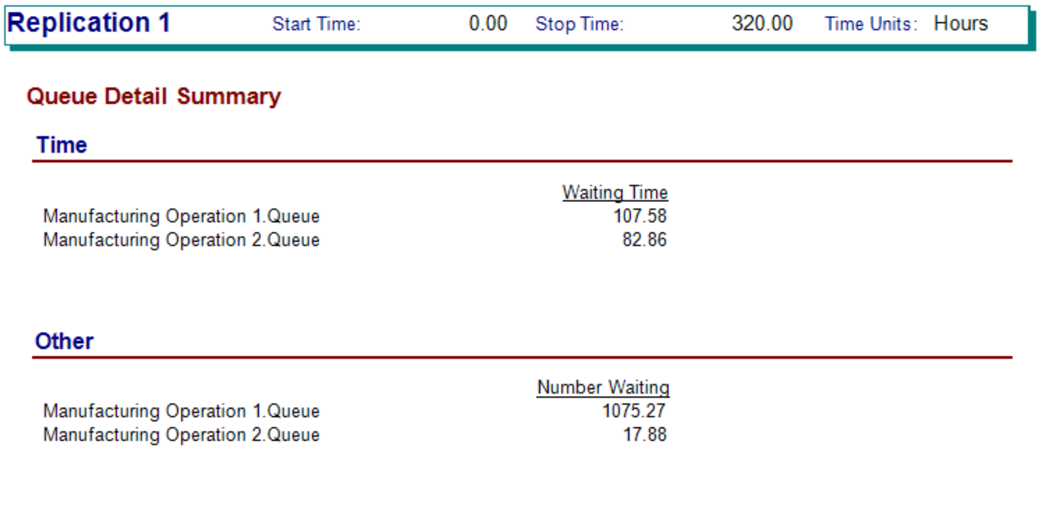


Figure 4. Manufacturing Facility with Quality Control ARENA Model

Once the Manufacturing Facility with Quality Control operation set-up is completed, run length is set to 320 hours (8 hours/shift * 2 shifts/day * 20 days). Once the simulation run is completed, it can be observed that 3210 parts (raw parts) arrived to the manufacturing facility. Of these 3210 parts, 2151 parts completed Manufacturing Operation 1. Among the parts that arrived to the Quality Control Station, 999 parts passed the inspection and 60 parts are send to Manufacturing Operation 2 for further processing, and a total of 1019 parts manufactured. Similar to the previous in-class hands-on example, Queue detail summary is examined to identify the waiting times and the number of parts waiting, as shown in Figure 5.


Replication 1 Start Time: 0.00 Stop Time: 320.00 Time Units: Hours

Queue Detail Summary

Time

	Waiting Time
Manufacturing Operation 1.Queue	107.58
Manufacturing Operation 2.Queue	82.86

Other

	Number Waiting
Manufacturing Operation 1.Queue	1075.27
Manufacturing Operation 2.Queue	17.88

Figure 5. Queue Detail Summary for Manufacturing Facility with Quality Control Example

Conclusions and Future Work

Hands-on learning is one of the most effective methods to support the learning experience in engineering technology courses. This paper shared two of the hands-on learning examples incorporated into Facilities Planning course where students are introduced a new software, ARENA by Rockwell Automation, to model the facility processes. The hands-on learning examples provided students an opportunity to apply the theory learnt in the lectures to virtual examples.

The future work includes implementation of additional in-class examples and project-based learning activities paired with appropriate questionnaires and surveys to measure students' approach, feedback and experience of learning through different applied learning activities.

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