Early Introduction to Computer Simulation Enhances Student Learning in Engineering

John Katona, B.S. and Megan O. Conrad, Ph.D.
Industrial and Systems Engineering Dept.
Oakland University
Rochester, MI 48309

Abstract submitted to the 2014 American Society for Engineering Education North Central Section Conference, Rochester, MI, April 4-5, 2014

Abstract:
Proficiency in computer simulation allows students the opportunity to develop experimental skills[1] while enhancing classroom performance[2]. In the Industrial and Systems Engineering (ISE) Department at Oakland University, simulation software is introduced to educate students in sophomore and junior level courses. Early classroom adoption of simulation tools allows students to understand and value simulation for problem solving in later classes or future jobs. Due to a partnership with Siemens PLM Software's GO PLM Program, Oakland University students have access to full versions of the Tecnomatix suite of simulation software. The suite includes Classic Jack, an ergonomic simulation tool that is taught in a variety of the ISE courses. In introductory courses, students use Classic Jack to generate data for statistical analysis. For advanced courses, Classic Jack allows the student to model problems in a visual way while also providing mathematic proof of a problem solution. This paper describes the ISE Department's implementation and teaching objectives for using Classic Jack in undergraduate courses.

Introduction:
Oakland University's Industrial and Systems Engineering (ISE) Department was established in 2006 and received ABET accreditation in 2009. The program began focusing on educating students in Product Lifecycle Management (PLM) in 2010. According to the university, "The objectives of the Industrial and Systems Engineering program are to produce graduates who will be able to design, develop, and implement systems which integrate people, materials, equipment, information and energy; will be capable of operating effectively in dynamic and diverse organizations; and will demonstrate a professional attitude, integrity and commitment to life-long learning in their work."

Oakland University students have full access to Siemens' PLM (Allen Park, MI) software package through the GO PLM Program, and every engineering student is introduced to two of the tools during their sophomore year. Additionally, students who choose ISE as their major will use PLM software in up to six additional courses. Initial tools introduced to all Oakland University sophomores include Siemens' Tecnomatix Plant Simulation and Tecnomatix Classic Jack. Plant Simulation is a discrete event simulation software used to create digital models of logical systems. It is especially useful for bottleneck identification and running what-if scenarios in manufacturing environments to evaluate process flow. Classic Jack is a human modeling and ergonomic simulation software which is used to design work so it is safe and efficient. It can be used to identify areas of a worker's body where the highest areas of stress exist to help in design or redesign of a safe work environment. The software can also be used to rearrange tasks and redesign work cells to reduce processing time and improve the work.

Later, experienced students will use other software and tools, including Process Simulate, Arena, NX, Catia, Solid Works, Team Center, and Robcad. This paper outlines the ISE Department's implementation of PLM software throughout the undergraduate curriculum. Experience modelling practical systems coupled with exposure to complex laboratory assignments provides a robust yet practical learning environment for the ISE student.

Discussion:

Early Introduction

As sophomores, all OU Engineering students take an introductory statistics and simulation course, entitled "Introduction to Industrial and Systems Engineering." The class focuses on probability and statistics while incorporating a simulation lab component. Students use Plant Simulation, a discrete event simulation software, during six of the lab sessions and Classic Jack for the final lab session. For each lab, the students are presented a simple simulation problem that reflects a real life system. The students are then expected to build a simulation model, collect and analyze data and make analysis decisions pertaining to the system.

An example of a practical model introduced to the students is the third lab assignment. In this lab, Plant Simulation assists students to models a coffee shop in which customers enter, wait in line, are serviced, and leave the store (figure 1). Randomness is reflected in the model with normally distributed arrival rates and processing times. Extra complexity exists in the model with a steady flow of customers from open to close, plus a morning rush and an afternoon rush. During these "rush" times, the model is no longer in steady state, with the line accumulating customers. The students vary the maximum queue length and number of servers to see the effect on the system. Average processing time and throughput data are collected to evaluate the efficiency of the system. Finally, the data is used to make recommendations on number of servers and queue length for optimal system efficiency.

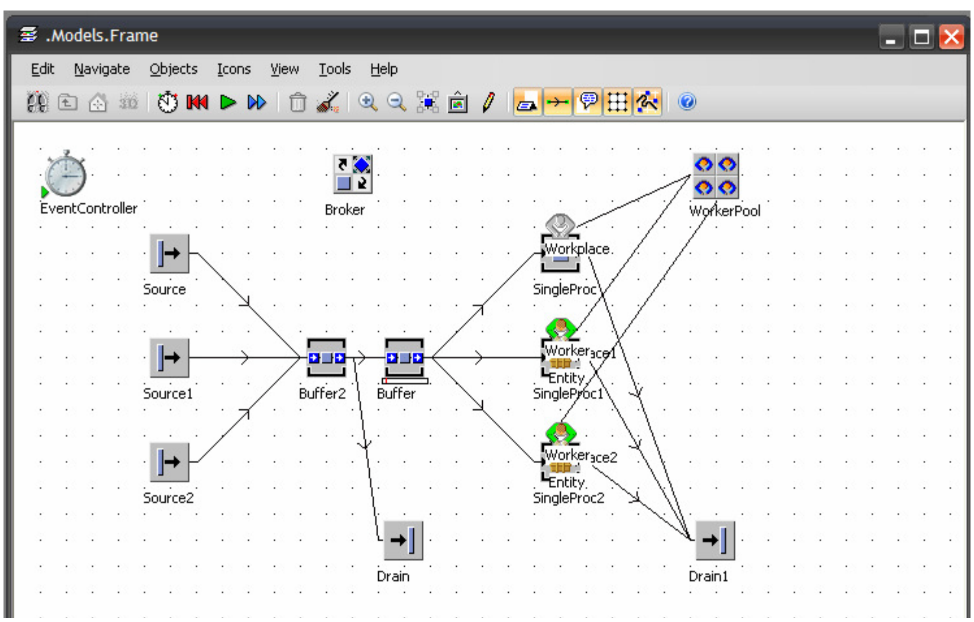

Figure 1. Simulation model of a coffee shop in Plant Simulation (Siemens PLM). The coffee shop model introduces students to processing times, queue lengths and throughput data which are then used to assess the number of servers required to optimize efficiency.

Proceedings of the 2014 ASEE North Central Section Conference

In a subsequent lab, the students build a small section of an assembly line with six machines and three workers to determine the bottlenecks and resource allocation (figure 2). A queue is added to the system to see the effect on throughput and processing time. Like the prior labs, data is collected to make decisions on the optimal design of the system. The assembly line lab challenges students even further than the coffee shop lab as they now are asked to actively decide the effects of changing the model and are required to specifically identify what data is important for determining optimal system performance.

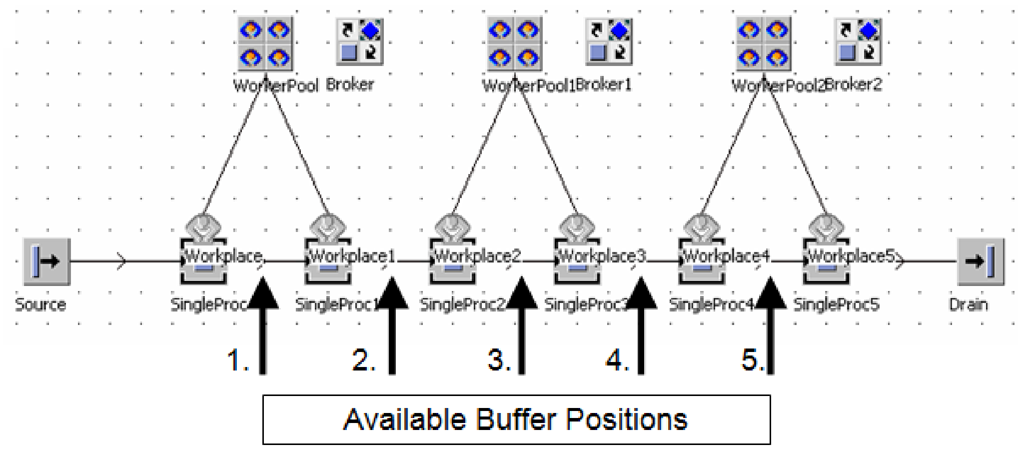

Figure 2. Assembly line model built in Plant Simulate (Siemens PLM). Students are challenged further by determining which variables, such as buffer position, are important for optimal system performance.

To accomplish the task, students build a separate simulation model of each optional assembly configuration for the system changing buffer locations. The students run each simulation, collecting the data deemed most useful. Some students record all of the statistics available from the simulation, while other more astute students record only throughput and time in system. For analysis, students use their data to decide which system layout would be best to recommend to an employer. This allows students to think critically about what performance measures are important in a manufacturing system. Obviously, throughput is important because it is the point where profits are achieved, but many students realize that reducing time in system is also important when evaluating manufacturing systems.

For the final lab of the sophomore class, Classic Jack Human Modeling software is introduced. Jack's 3D interface allows students to visualize a worker as they complete a series of tasks in the workplace. The students design a task consisting of moving weighted parts around a workspace (see figure 3). Once the job is defined, timing to complete the task is obtained for the worker and compression forces in the lower back are recorded. The student are able to alter the weight of each object and changes in stress are revealed in the lower back compression forces. Next, the worker is changed from a 95^{th} percentile male, who is very large, to a 5^{th} percentile woman, who is much smaller. All of the tasks are repeated with each varying object weight for the female worker, and the new timing and lower back compression forces are obtained.

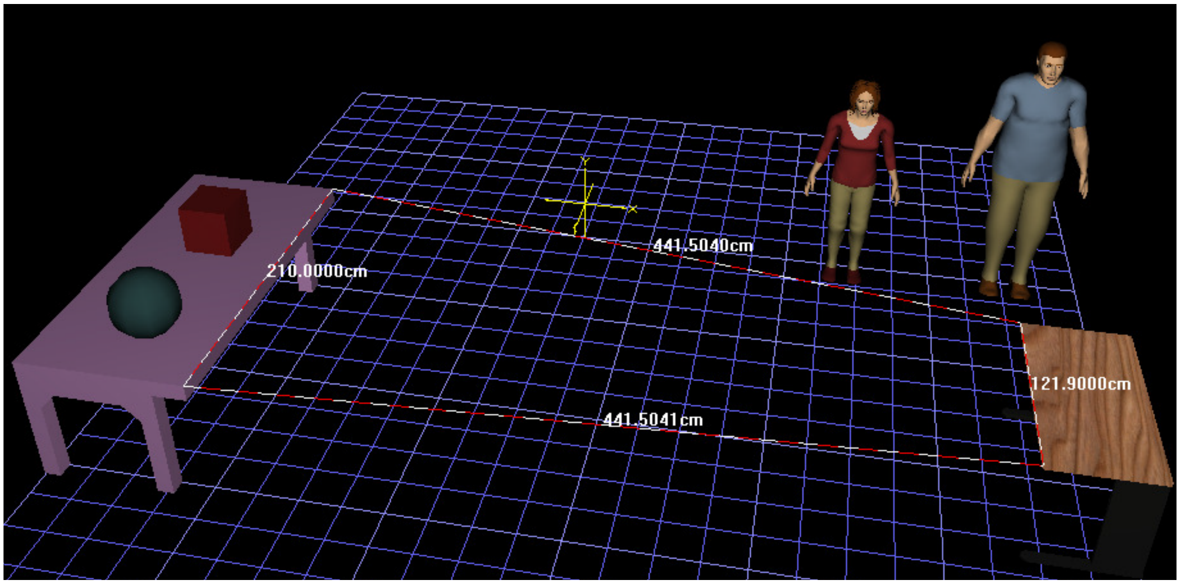

Figure 3. Carrying task simulation built in Classic Jack (Siemens PLM). The model is used to analyze timing and low back strain in a 95th percentile male and a 5th percentile female.

Once the simulations are completed and many timing and lower back analysis documents have been created, the data is analyzed to assess the overall system. The students export data to Excel and create graphs and charts of timing data and lower back compression data. The exercise helps the students to visualize that data, in order to understand the underlying principals of ergonomics. From the data, students will observe the differing trends between male and female workers of widely differing heights, and they will observe the point when the object weights become too large for workers to safely lift and transport.

Reinforcing the Tools

ISE students later enroll in an Ergonomics course focusing the design of products or workspaces to accommodate the human body's size and limitations. In the course, multiple labs using Classic Jack are used to reinforce concepts from class and provide additional methods for problem solving. For example, in an early lab, students record anthropometric data from each student in the class and use the dimensions to design an automobile cab customized to fit the class measurements. Once all the data is collected and the dimensions of a car interior are defined, computer simulation is used to recreate the vehicle interior according to those specifications. Human modeling is used to check the feasibility of the dimensions for the sample population by placing individuals of various sizes into the driver's seat (figure 4). The final lab report consists of recommendations for proper dimensions of a vehicle interior, based on the class anthropomorphic data as well as the visual fit observed in the Classic Jack software. The report also includes a discussion of the critical areas of the model which may require further thought regarding adjustability in order to properly fit the entire sample population.

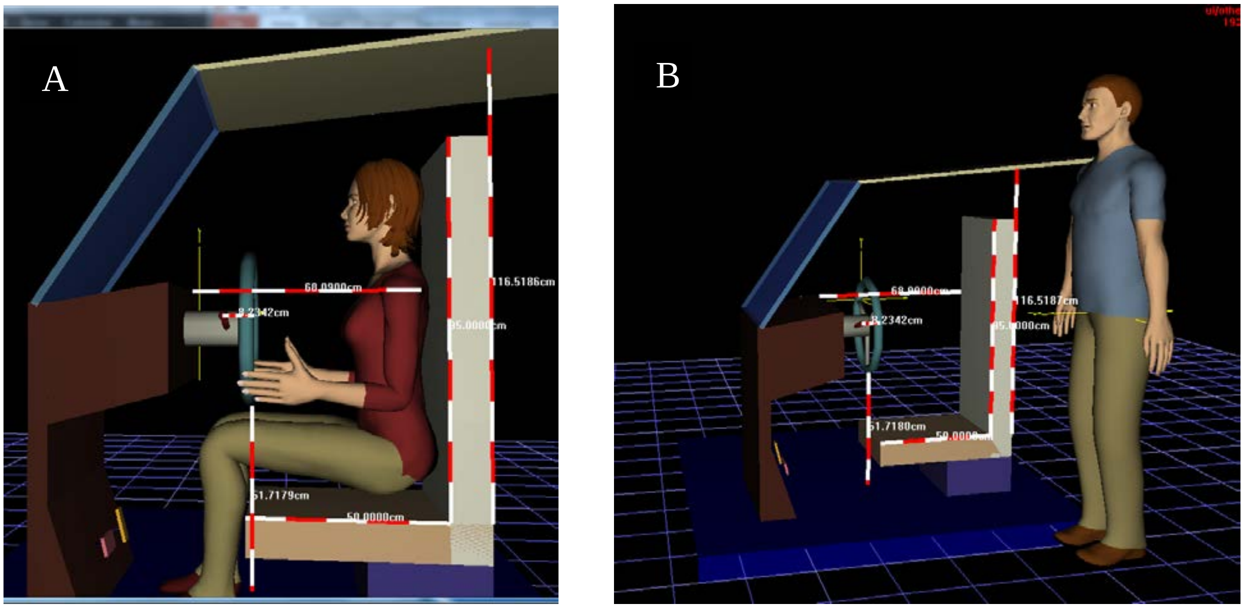

Figure 4. Classic Jack model of a car interior. The students define the dimensions of the driver's seat and controls based upon anthropometric data collected from each student in the class. The students then visually assess the dimensions of the vehicle using by fitting a 5^{th} %ile female (A) and 95^{th} % male (B) in the vehicle.

Another lab from the junior level ergonomics course consists of building a job within a work cell and rearranging both the workspace and the order of tasks to achieve the fastest and safest standardized work. The original work has a poor layout and consists of tasks that are unsafe for workers to repeat regularly. Once the students identify problem areas in the job, they are able fix the issues by rearranging the model. A focus of the lab is timing efficiency, so the students conduct many iterations of "process improvement" on the model until it is as precise and efficient as the student is willing to achieve. One interesting aspect of this lab is that improvements are almost always possible, but the level of improvement is dependant on each student's enthusiasm. The job can go from 56 seconds per iteration to under 20 seconds. The students have the goal of achieving a time of less than 30 seconds for the entire job, but many students become competitive and achieve a lower task time.

After obtaining a solid foundation in the PLM tools, ISE Seniors expand their knowledge of simulation in a focused discrete event simulation class. The class details all aspects of discrete event simulation, from random number generators to data mining to model design and construction. Arena is primarily used for this class, but Plant Simulation is also implemented into the curriculum. The opportunity to use multiple software packages provides students experience comparing various simulation tools that offer similar capabilities.

As seniors, the students are able to model exceedingly more complex systems than in any of the other classes with a simulation component. In one assignment, an entire hospital emergency system is modeled. The model is extensive, consisting of an arrival/routing subsystem, a reprioritization subsystem, three regular processing subsystems, allocation of resources, a critical patient subsystem, and a discharge subsystem. Each subsystem interfaces to create a large dynamic system model allowing modeling of complex system behavior. Such large scale modeling examples would not be feasible if the students were not already comfortable with the PLM software and its capabilities.

Finally, in a senior elective course called Robotic Systems, a robot and robot-cell simulation tool by Siemens, called Robcad, is currently being integrated into the curriculum. The software allows students more "hands-on" robot time, with virtual robots taking the place of the more expensive and dangerous physical robots. Also, the students will be able to test their math in the simulation before using the physical robot, improving safety and making their time with the physical robots more valuable.

Conclusion:

It is important to introduce students to PLM tools early in their engineering degrees. Oakland University students are first introduced to computer-aided design, discrete event simulation, and human modeling in introductory courses, even before the engineering curriculum diverges and the students have committed to a field of engineering. When Siemen's PLM tools are used in the freshman or sophomore curriculum, it provides students a solid base in the software allowing them to later achieve an in depth understanding of the tools for solving complex problems. Similar to advanced Calculus courses building off of the previous Calculus courses, advanced engineering courses can build up further knowledge of PLM and simulation when a foundation of PLM has been properly established. This is additionally beneficial to the students, because they develop a skill set early on that might be applied in their engineering jobs, internships, or co-op positions as the need for simulation engineers rises throughout industry [3]. Students find value in training in practical PLM tools that can directly be applied to future jobs creating a mutually beneficial situation for both the student and the employer.

Bibliography:

1. Quinn, R.G. "The E^4 Introductory Engineering Test, Design and Simulation Laboratory." *Journal of Engineering Education.* 82(4): 223-226, 1993.
2. Koh C., Hock, S.T., Tan, K.C., Fang, L., Fong, F.M., Dan, D., Lye, S.L., Wee, M.L. "Investigating the Effect of 3D Simulation-Based Learning on the Motivation and Performance of Engineering Students". *Journal of Engineering Education*. 99(3), 237-251, 2010.
3. DeVin, L.J., Jagstam, M. "Why we need to offer a modeling and simulation engineering curriculum". *Proceedings of the 2001 Winter Simulation Conference*, 1599-1604, 2001.

Biographical Information:

JOHN KATONA: John Katona is a master's student and teaching assistant in the Industrial and Systems Engineering Department at Oakland University (OU) in Rochester, MI. His research is focused on the use of modeling and simulation aimed to improve healthcare systems. John has been instrumental in developing several PLM simulation labs that have been implemented in introductory, advanced undergraduate and graduate level courses at OU.

MEGAN CONRAD: Megan Conrad, Ph.D. is an assistant professor in the Industrial and Systems Engineering Department at Oakland University (OU) in Rochester, MI. Her research interests include ergonomics, neuromechanics, and rehabilitation engineering. She has recently been developing new courses and labs for the *Ergonomics and Work Methods* and *Human Factors* courses in her department.