An Interactive Web Based Virtual Factory Model for Teaching Production Concepts

Ramanan Tiruvannamalai, Lawrence Whitman, Hossein Cheraghi, and Ashok Ramachandran
Department of Industrial and Manufacturing Engineering
Wichita State University
Wichita, KS 67260-0035

Abstract
Teaching students with little factory experience is difficult. Many concepts, such as push, pull, buffer sizes and variability, are tedious to explain without visiting a factory. Simulation tools play a key role in presenting these concepts. A web-based interactive Virtual Factory model provides students an opportunity to visualize factory concepts and methodologies as well as the ability to change resource parameters, simulate over the web, and view results immediately to understand the impacts of decisions. This improves student learning and retention, as well as increasing the application of these concepts. The paper presents the need for a virtual factory, its design, and provides future directions.

Keywords
Production control, manufacturing, education, simulation.

1. Introduction
Structured teaching environments provided by many schools and universities for production systems courses focus on acquiring knowledge based on books and case studies. But the outcome of knowledge and skill acquisition does not necessarily result in the ability to apply knowledge appropriately to different situations.

Extensive research work has been carried out in the field of simulation and its applications to improve the manufacturing environment. Computer simulation technology is widespread and finds great use in educational institutions as knowledge based learning and teaching tool. Students use simulation tools for learning and for knowledge construction. Simulation, as a learning tool, emphasizes that the learner controls the technology rather than technology controlling the learner. Simulation environments help the learner to set their own problems, and formulate and test their own hypothesis. This helps the learners in improving their knowledge and problem solving skills. The use of simulation in a learning environment work is based on “Piagetian theory” [1], which emphasizes self discovery and peer communication.

The objective of this paper is to present the design of a web-based interactive Virtual Factory (VF) model which helps students understand, synthesize and transfer the knowledge learned in class to a complex real life production environment. The factory model was created using the discrete event simulation tool, QUEST. The Virtual Reality Modeling Language (VRML) was used for enabling a web based factory simulation model and to provide 3D visualization of the shop floor. Students can navigate in the web-based factory model and interact with the resources. They can change parameters, add new resources, and simulate several “what-if” scenarios to analyze the impact on the whole system with simple point and click actions. The web enabled feature provides uninterrupted anytime, anywhere controlled access to students for understanding the factory dynamics and tradeoffs between different elements of the factory. The web-based VF model is an effective teaching tool for enhancing student education by complementing traditional instruction methods.

2. Using Simulation for Teaching
Kuyper, Hoog, & Jong, [2] propose an instructional simulation tool called SIMQuest. This tool was developed for gaining insight about the subject. Instructional objectives were set and learning material was formulated to address the conceptual learning issues. Subject matter theories are very abstract for students as they lack dynamics and visual
representation. Usually, lab experiments help to train for procedures and learn about real life contexts, but often fail to connect with theoretical insights. Instructional simulations can be used to merge the gap between theory and practice. Theories often deliver formulas for calculating a certain measure for practice, whereas labs provide the value for these measures, but still the underlying concept for these measures and their relationships are unclear for the learner. Instructional simulations aid in understanding the underlying concept for determining the behavior of the system. Instructional simulations are not meant for replacing traditional lecturing, but rather are used to enhance difficult to understand processes with dynamic representations/visualizations.

There are many drawbacks of using simulation tools for conceptual learning. Sometimes, students who perform well in simulations have learned to play the game better rather than learning. Learners often might not exploit the full functionality of a simulation tool. This might lead to different levels of understanding with students. In some simulation experiments, learning and performance are unrelated. During the student’s early simulation approach, there is a significant correlation between learning and simulation. This is because of student willingness to know more during early stages. As time progresses, the results show that relationship between learning and simulation statistically vary [3].

Structured teaching environments provided by many schools and universities focus on acquiring knowledge based on books and case studies. But the ultimate test of knowledge and skill acquisition is usually not in knowing; rather it depends upon the ability to apply knowledge appropriately to different situations. This helps in the translation of student knowledge into behavior. Case studies usually illustrate a single concept or a theory and fail to address the nature of system dynamics [4]. Traditional teaching methods and learning environments are often boring and less challenging. The simulation provides students with a challenging real life factory scenario, which helps them to learn outside the box concepts and tradeoffs between different elements of the system [3].

The simulation model is an effective teaching tool for enhancing student education by complementing traditional instruction methods. A study by Gokhale [5] showed that students remember only 10% of what they read and 20% of what they hear. However, he found that students remember 90% of what they learn from simulations. Well designed and implemented computer simulations could revolutionize education [5]. The simulation models can overcome many deficiencies of traditional teaching methods by not only helping students to identify the problems but also to determine the best way to solve problems. Simulation allows students to think like managers for understanding the problem, determining the root cause and solving it more efficiently. One of the main advantages of using simulation is that it helps students to visualize the interfaces and interactions between men, machinery and material, and to analyze operational issues and investigate different alternatives [3].

There are several advantages of using simulation models in teaching resource management concepts as it represents a real production environment with inherent variability in a system. Resource management concepts can be embedded in simulation tools to help in achieving the desired learning objectives into the curriculum. A simulation model should be modified from the student’s perspective to address the course requirements. Simulation models should focus on the learning objective and due care should be taken not to over burden the student, as this may lead to difficulties in retaining the concepts. Students learn more when they work in teams. Teamwork helps in improving their thinking and decision making skills. Simulation models complemented with good visualization can play a significant role in effective learning [3].

Students have found simulation assignments more interesting and effective than the traditional assignments. “Students realize the potential of simulation as a source of constructive feedback that enables them to take more responsibility on their learning” [6]. Simulation tools in education can provide a contribution to active learning only if they are actually incorporated into the curriculum. Students clearly understand the difference between simulation and reality. A simulation is always a supplement and cannot replace reality. Knowledge gained using simulation must be applied on the real shop floor to reap the benefits. Knowledge is not power until it is applied [6]. Having presented the need for simulation models to teach factory concepts, the design of a web-based simulation model is now presented.

3. Web Based Virtual Factory Model
A virtual factory (VF) is a computer mockup of a real shop floor where new designs can be tested in a virtual environment. This laboratory assists students in understanding the complex factory dynamics for different situations by making decisions. In the VF, the interaction between various elements of the factory and its impacts on the whole system can be studied. A number of ‘what if’ analysis studies can be conducted and performance criteria like flexibility, lead-time, throughput, inventory levels, labor and equipment needs can be varied to understand the details [7].

The Virtual Factory (VF) simulation models were modified for easy web access. The ability of simulation models to be invoked as per user request from the server was accomplished with an ASP component. After the model was web enabled, an interactive user interface was created using VRML for effective 3D visualization. This user interface allows students to change resource parameters for simulation. These changed parameters are transferred to the simulation model in the server using ASP. The results of the simulation are displayed back to the users immediately in real time.

3.1 Modules

The VF has several modules each progressively more complex. Module 1, presented in figure 1, demonstrates the impacts of buffer size/capacity on throughput with a simple factory floor, where users can change only the buffer capacity of each buffers. Module 2 presents the impacts of cycle time, setup time, and breakdown variability on throughput with a complex system, where users can change setup times, cycle times, and downtimes, as shown in figure 2, on all the resources on the factory floor. The next module presents basic factory dynamics using the concept of ‘Penny Fab One’ from the Factory Physics Textbook [8] and demonstrates the simple relationships between Work In Process (WIP), Cycle Time (CT) and Throughput (TH). Also illustrated with this module is ‘Best-Case Performance,’ ‘Worst-Case Performance’ and ‘Practical Worst-Case Performance.’ Variability basics are demonstrated with the ‘Penny Fab Two,’ shown in figure 3, demonstrating the relationship between WIP, CT and Throughput and process time variability (Low Variability, Moderate Variability, High Variability), flow variability, queuing, queue sharing, breakdowns, and the effects of blocking and starving. Advanced modules are also available showing variability buffering and also a module based on Goldratt’s ‘302 simulation model.’ This advanced module is used as part of the final exam to evaluate student ability to synthesize all concepts in the class.
3.2 Module Results

Students then run the simulation and have several options in which the results can be viewed. Whereas the simulation is run on the server, students view helpful hints about Factory Physics [8] on the screen. The student may select from a wide range of options which are: full simulation report, a comma delimited report, throughput report, and several graphs (showing CT, WIP & TH as shown in figure 4); Utilization; Statetimes-punch; Statetimes-stamp; Statetimes-rim; Statetimes-deburr; Stamp M/C Buffer Waiting Time; Rim M/C Buffer Waiting Time; Deburr M/C Buffer Waiting Time, as well as see a snapshot of the shop floor.
4. Conclusion and Future Recommendations

The Virtual Factory was first used in Fall 2003 and is currently being used in Spring 2004 at Wichita State University. Student feedback has been very good. After the Fall 2003 class, a survey was conducted of student perceptions about the use of the virtual factory. As can be seen from figure 5, student’s viewed the virtual factory assignments favorably. Currently, additional models are being built with the express purpose of demonstrating basic concepts in class by the instructor. These concepts include single card and two-card kanban, ConWIP, bottleneck management, and utilization. These models are typically used for classroom demonstration and will not provide the interactive capability of the modules previously described. As this simulation is accessible over the web, anyone at any location can use this tool to learn factory concepts. A more comprehensive qualitative evaluation on student comprehension of major class concepts is currently in progress.

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Figure 5. Student perceptions of the ease of use of virtual reality

References