eLearning Activities for Teaching Manufacturing System

Authors:

Muhammad Sohail Ahmed, Ph.D, sohail@mie.eng.wayne.edu, Wayne State University, Detroit MI 48201 USA
Nancy L. Baskin, M.Ed., baskinn@focushope.edu, Greenfield Coalition, Detroit, MI 48238 USA
Gregory L. Tonkay, Ph.D., jef2@lehigh.edu, Lehigh University, Bethlehem, PA, 18015 USA
Emory W. Zimmers, Ph.D., ewz0@lehigh.edu, Lehigh University, Bethlehem, PA, 18015 USA

Abstract — *Self-directed and experiential learning is significant for effective engineering education. Certain cognitive processes such as problem-solving and reasoning are particularly important to the successful completion of engineering tasks. Because engineering often involves innovation and invention, creativity and teamwork are crucial. eLearning, instruction in a web-based environment, offers a avenue for higher level thinking: images can be dynamic, parameters can be manipulated, and outputs can be simulated. However, many online engineering courses do not make use of these technological possibilities. Instead, courses employ text heavy HTML pages and display too many static images. Despite the availability of research supporting the benefits of interactive education, this knowledge is under-utilized in most existing eLearning products and services. This paper describes three activities from Manufacturing Systems II, a course in the Greenfield Coalition (GC) Learning System. GC courses incorporate a blended learning approach where learning is situated in three different environments: classroom, web-based, and experiential. The activities are presented using discovery and experiential learning to convey concepts that are difficult to teach in a traditional classroom. Web-based activities and classroom discussions help create interactive learning. Some of the activities begin with students first encountering a real-world manufacturing situation in a web-based environment. They explore a condition and discover, individually or collaboratively, the effects of various parameters on specific outputs. The classroom discussions that follow elaborate on the material and clarify concepts. Activities that incorporate discovery learning in an interactive environment can improve student learning and retention. Learners are able to problem-solve in authentic situations presented in a web-based format and discover how engineering concepts interrelate. When a real-world environment is created using simulation and animation on the web, students are better able to transfer their learning to the workplace. Effective eLearning materials are dependent upon the successful combination of real world content, technology and interactivity.*

Index Terms — *Experiential learning, engaged learning, eLearning, blended learning, web-based learning tools*

INTRODUCTION

eLearning is one of the hottest topics in higher education since the 1990s. After passing through its infancy, researchers and application managers all over the world have started researching the process in detail. Though the enormous growth of the Internet has opened new means of delivering university courses without geographic boundaries [1], several lessons have been learned about their effectiveness.

Engineering represents a major category of adult education that is critical to most aspects of modern society. Applying eLearning to engineering education is not a new topic, Gramoll's [2] scaleable Internet portal for engineering mechanics courses provide a lead in such applications. However, because of the different learning skills set for the engineering, education researchers are redefining the ways and methodologies of engineering education [3], which will change the way engineering education is delivered online.

This paper describes the problems with eLearning in general, and its application within engineering education in particular. It highlights the possibilities of using various teaching strategies for effective learninng in the eLearning domain, outlines a modified eLearning concept for engineering education, and details three examples from a Greenfield Coalition course.

PROBLEMS WITH ELEARNING

Rolf Ahdell [4], defined eLearning as an "effective and engaging learning anywhere at anytime, developed and delivered using information technology." It is a valuable extension of the distance education, enabled by the new information and communication technologies. Distance education normally occurs in a different place from teaching and as a result requires special techniques of course design, instructional strategies, methods of communication, as well as organizational and administrative arrangements [5]. In the European Union, eLearning is being seen as a major opportunity to move Europe forward to a knowledge society [6]. The US eLearning market has a projected value of $11.5 billion by this year [7] while the European market is expected to be worth $4 billion by 2004 [8].

Due to the flexibility provided to students/trainees and teachers/trainers, both in space and time, eLearning may be a source of great joy to its users and an important source of financial resources for many organizations. However, eLearning is based on the cooperation of geographically distributed participants. Many of the activities the participants are supposed to perform do not have strict time schedules, but do have time constraints that must be respected. If these constraints are not fulfilled, severe problems may occur and the success of a specific task or action may be in jeopardy. These kinds of problems are difficult to solve, because of the distributed nature of the resources and participants of an eLearning environment [7].

Poor usability of eLearning contributes to disappointing results for many companies for the following reasons:

- Failure to create a lasting advantage in a crowded and competitive marketplace.
- Failure to develop ongoing customer loyalty. Despite the trend toward lifelong learning, people will be reluctant to continually return to services that they find difficult to use.

In a survey conducted by the Jane Messey [9], it was reported that 61% of all respondents rated the overall quality of eLearning negatively - as fair or poor. The following describes some problems associated with eLearning content.

Poor Design

Poor design is one of the biggest problems with eLearning. According to Margaret Rueda [2], many people are developing eLearning that is a complete disservice to the entire industry. eLearning must be engaging and interactive in order to be effective. The most promising feature of multimedia and network-based media is its ability to interactively display complex information and concepts in an accessible and easy to understand, animated graphical form [3]. Also, though eLearning is a great tool, some topics are better covered in a facilitated setting. For example, it would be difficult to practice teambuilding skills within an eLearning environment.

Boring, Text Heavy Content

One of the roadblocks in online courses and training is static content with weak interactivity [9]. Much of eLearning is where eBusiness was seven years ago, but instead of vendors creating online catalogues, trainers are now developing online textbooks. Most of the today's eLearning implies scrolling text-heavy HTML-pages. Multimedia and network-based media technologies have the potential of providing a mean for dealing with these issues in a dynamic, provocative, and cost-effective manner that not only will increase the effectiveness of the educational program but will also increase the quality of the resulting students [5, 6].

Effects are Hard to Measured

The overall impact of eLearning remains uncertain, because managers/evaluators fail to measure effectiveness. In a survey of an online course, 77% of the respondents do not track the number of employees who take advantage of online training, and two-thirds do not measure the effectiveness of their net-based programs [10]. It is difficult and time-consuming to measure effects quantitatively, and therefore many companies only use qualitative feedback instead.

Technological Issues

Smallwood and Zargari [11] pointed out occasional technology problems as an issue with the online learning. Technological issues, such as Internet connectivity & availability, bandwidth, metadata, information system, standardized structure, redundancy due to poor database architecture, etc. play a vital role in the application of any eLearning program. They can hinder the utilization of courses by professors/trainers and equally students can get distracted from the first goal of eLearning, the learning itself. Security and reliability will be of high priority as cross-references and technical collaboration between courses increases. These issues will play a major role in web portals such as Gramoll's courses web portal [3].

ENGINEERING EDUCATION

Although there are many different types of engineering (e.g., aerospace, chemical, civil, electrical/electronic, industrial/manufacturing, mechanical, mining, nuclear), the fundamental nature of engineering is similar across all domains [12, 13]. Engineering is undergoing an identity crisis. According to Williams [14], the mission of engineering changes when its dominant objective no longer involves the conquest of nature, but rather the creation and management of a self-made habitat.

Certain cognitive processes such as problem-solving and reasoning are particularly important in engineering tasks. Since most engineering methods involve some form of mathematics, this is a critical learning domain. In addition, engineering often involves innovation or invention; hence creativity is very important.

Most modern engineering activities are conducted in a team setting with a great deal of interaction among team members. This makes social learning and development highly relevant to engineering education [15, 16]. Furthermore, many engineers must perform some sort of management function, making this domain of skills relevant as well. Like most other professionals, engineers must engage in lifelong learning in order to stay current in their field. This means that self-directed and experiential learning, as outlined in the theories of Cross [17] and Rogers [18], is significant for engineering education.

Denning [5] states that future engineers must, in addition to being competent in engineering basics, be skilled listeners for concerns of customers or clients, be rigorous in managing commitments and achieving customer or client satisfaction, and be prepared for ongoing learning. He discusses the changes required in university programs to accommodate these needs. Jones [19] outlines the role that educational technology needs to play in continuing education for engineers, suggesting that theories of learning that focus on media [20, 21] are relevant to engineering education.

SOLUTION

Despite the availability of new research in areas such as learning sciences, cognitive science, reasoning, instructional design and technology, collaborative learning, learner-centered design, and learning technology, the knowledge is under utilized in most currently available eLearning products and services. Unfortunately, too many eLearning companies/universities just deliver course materials rather than create knowledge-building communities. Too many of them stress memorization of facts that are tested with multiple choice questions, rather than having the learners actually *use* their new knowledge and skills as part of collaborative projects with other online learners. In order to formulate any new methodology for Engineering Education and eLearning that can cater to the above problems, its content should address the following types of learning: media focus, experiential, and social. This framework could be referenced as the eLearning Content Domain (see Figure 1).

The social learning theory of Bandura, [14], emphasizes the importance of observing and modeling the behaviors, attitudes, and emotional reactions of others. Bandura states, "Learning would be exceedingly laborious, not to mention hazardous, if people had to rely solely on the effects of their own actions to inform them what to do." Vygotsky's theory is complementary to the work of Bandura on social learning and a key component of situated learning theory [15].

Vygotsky's theory [16] was an attempt to explain awareness as the product of socialization. For example, when learning language, our first words with peers or adults are for the purpose of communication; but once mastered, they become internalized and allow inner speech. Social learning emphasizes the following:

- Individuals are more likely to adopt a modeled behavior if it results in outcomes they value.
- Individuals are more likely to adopt a modeled behavior if the model is similar to the observer and has admired status and the behavior has functional value.

Experiential Learning

Rogers [22, 18] distinguished two types of learning: cognitive and experiential. The former corresponds to academic knowledge, such as, learning vocabulary or multiplication tables; and the latter refers to applied knowledge, such as, learning about engines in order to repair a car. The key to the distinction is that experiential learning addresses the needs and wants of the learner. Rogers lists these qualities of experiential learning: personal involvement, self-initiated, evaluation by learner, and pervasive effects on learner.

Experiential learning is equivalent to personal change and growth in which the teacher is to facilitate such learning. This includes: (1) setting a positive climate for learning, (2) clarifying the purposes of the learner(s), (3) organizing and making available learning resources, (4) balancing intellectual and emotional components of learning, and (5) sharing feelings and thoughts with learners but not dominating.

Media Focus Learning

The symbol systems theory developed by Salomon is intended to explain the effects of media on learning. According to Salomon [20], the symbol systems of media affect the acquisition of knowledge by highlighting various aspects of content and by coding and recoding to ease elaboration. For example, Salomon suggests that television requires less mental processing than reading and that the meanings secured from viewing television tend to be less elaborate than those secured from reading (i.e., different levels of processing are involved).

When developing a distance delivery course, designers must provide a way for students and instructor to interact [23]. It should be engaging and interactive in order to be effective. eLearning is a great tool, however, some topics are better covered in a facilitated setting. For example, it would be difficult to practice social skills, such as communication, with eLearning. Many of the eLearning tools like Blackboard and WebCT have the online chat and discussion boards, but they fail to emulate a live group setting. In an ideal eLearning situation, a face-to-face component still exists and a blended learning experience is created.

GREENFIELD COALITION

Greenfield Coalition (GC) at Focus:HOPE is coalition of five universities, seven manufacturing companies, the Society of Manufacturing Engineers, and Focus:HOPE. GC was formed to create a revolutionary educational experience leading to bachelor degrees in engineering and engineering technology. The National Science Foundation funds the Coalition; it aims to integrate academic studies and manufacturing skills learned in the workplace. The GC vision leverages technology to enhance and accelerate progress toward the degree [24].

GC's instructional design strategy is built on Gagne theory [25]. Gagne identifies five major categories of learning: verbal information, intellectual skills, cognitive strategies, motor skills, and attitudes. The significance of these classifications is that each type of learning requires different types of instruction, because distinct internal and external conditions are necessary for each type of learning. Gagne suggests that learning tasks for intellectual skills can be organized in a hierarchy according to complexity: stimulus recognition, response generation, procedure following, use of terminology, discriminations, concept formation, rule application, and problem solving. The primary significance of the hierarchy is to identify prerequisites that should be completed to facilitate learning at each level. Doing an analysis of a learning/training task identifies prerequisites. Learning hierarchies provide a basis for the sequencing of instruction.

In addition, Gagne's theory outlines nine instructional events and corresponding cognitive processes:

- Gaining attention (reception)
- Informing learners of the objectives (expectancy)
- Stimulating recall of prior learning (retrieval)
- Presenting the stimulus/content (selective perception)
- Providing learning guidance (semantic encoding)
- Eliciting performance (responding)
- Providing feedback (reinforcement)
- Assessing performance (retrieval)
- Enhancing retention and transfer (generalization).

GC incorporates Gagne's theories into all instructional materials. In so doing, they follow a blended learning approach as seen in Figure 2. The approach includes classroom instruction for discussions and group collaboration; online components for simulations, animations, and other media; as well as an experiential component involving both shop floor activities and case studies. It encompasses all the learning theories that effect engineering education and eLearning. GC's approach focuses on the articulation of clear and consistent objectives for classroom learning as well as learning in work-related activities [24].

DESIGNING DEVELOPING AND DELIVERING CONTENT

When designing a course, a team of subject matter experts from academia and industry collaborate with an instructional designer and a programmer/media specialist. The goal is to create an instructionally-sound, technically-supported, engaging course or case study. The resulting materials are inclusive of key manufacturing engineering concepts and directly applicable to real-world, on-the-job experiences. Often these materials include templates, tools, and step-by-step instructions used by practicing engineers.

Using Gagne's Nine External Events of Instruction as a guide, GC is able to maximize the effectiveness of instruction, add relevance to the content, and foster an active learning atmosphere. At the commencement of a course, students are posed with a situation or set of questions to stimulate and engage thought processing regarding the concept at hand. These situations and questions relate to real world problems that do not have one discreet answer. Rather, there are many potential solutions with differing costs and benefits. The learning activities that follow, encourage learners to do their own investigations, challenge typical solutions, and practice the skills and techniques that will be necessary on the job.

An introduction to the session content occurs in one of the following ways: reading material, a web-based environment, or a classroom discussion. Students come to class prepared to discuss issues related to topic at hand. The instructor facilitates a discussion and gives feedback to help foster social learning skills. The instructor focuses the learners' attention on an experiential learning situation. The activities are focused on solving situations faced within engineering environments, and the questions are pertinent to the outcome. Students are given real time examples and facts. This is exemplified in case studies where learners are challenged to determine the scope of the problem, how it can be solved, and what materials – textbook, Internet, instructor, knowledge and experience of peers – are essential for completing the activity. Finally, students end up solving an issue, are able to relate it to the concept, and are better able to apply theoretical concepts on the job.

MANUFACTURING SYSTEM COURSE

Three activities, developed using the Greenfield Coalition paradigm, are detailed below. These activities are the part of a Manufacturing System course. The descriptions show how the activities were designed to facilitate the learning process.

The selected examples are from the session *Production Concepts & Mathematical Models*. The objective of this session is that the learners will be able to calculate basic performance attributes of manufacturing systems such as measures of production rate, capacity, and manufacturing lead-time. The students read about the concepts of production rate, capacity, utilization, availability, and work in process. They are asked to discuss certain scenarios, such as, whether or not it is it possible to have 100% availability. They are invited to use their experiences to discuss different machining and assembly operations. The classroom discussion creates an environment where students are able to share their experiences and learn from one another.

Machining Process and Production Rate

The activity, Machining Process & Production Rate, emphasizes discovery learning (see Figure 3). As noted earlier, engineering education revolves around the norms of analysis and formulas. This is an attempt to help students discover relationships using a cause and effects activity. Students are given a machining operation (mill or lath), they are able to change manufacturing parameters such as machining time, work handling time, batch size, etc. and see the effects on the production rate and the batch time. Until this point, the students have not gone through the basic equations for production rate and batch time. All they know up to this point is that operation time, batch time, and scrap may affect the production rate. At the end of the activity, students are asked to point out what parameters affect production rate and the concerns associated with a cycle time increase.

These responses are discussed in the classroom. Instructors can create a discussion based on the learner responses. They can link the input parameters to response and highlight the empirical or theoretical relation. Instead of just showing the students formulas, a bigger picture of cause and effect was shown to get the students to discover the formula.

Assembly Line and Production Rate

In the second activity, Assembly Line & Production Rate, the students explore the difference between assembly and process. The focus is on the effect of length of transfer line on the production rate and the buffer size and the interdependencies of various workstations. Students are introduced to parameters that can affect the production rate of an assembly operation. They are shown how individual operations/workstations and cycle time effect the production rate. In the web-based activity, they get to manipulate a simulation of assembly line.

This assembly line has five operations/workstations along with one receiving and a shipping station (see Figure 4). Students have the ability to modify the location of the workstations, the speed of the transfer line, and the cycle time of operations. By running the simulation, they can see the simulated production time and rate and the work in process. They have the option of making the simulation run for different sizes and speeds of the transfer line and cycle time. The activity ends with various questions about the effects of various parameters on the production. The answers are captured online, so the instructor is able to review them before class and pattern a discussion based upon learner understanding. This activity helps students to discover the dynamic nature of the assembly line and discover the effect of manufacturing parameters on the assembly production rate.

Capacity and Resource Allocation

The third activity deals with capacity and resource allocation. The focus of the activity is on the learners being able to demonstrate decision-making skills for issues involving capacity. They are introduced with the concept of plant capacity and its relation with the fluctuating demand. The activity starts with a brief discussion about the concept of capacity adjustment, using adjusting machines, and schedules and time.

They are given a scenario where they need to make a decision regarding capacity and resource allocation. They are able to use a web-based tool to help them with the calculations required for a sound decision (see Figure 5). The tool gives learners the ability to change the number of machines, the hours for the shifts, and/or the number of shifts per year to find out if the system is over or under capacity. The students are asked various questions regarding their decisions. The classroom discussion outlines the importance of resource allocation based on cost and time including, in some cases, the loss of business and good will.

CONCLUSIONS

Delivering online courses and training requires more than putting the text on the web. eLearning content should be interactive and exiting. Engineering curriculum is evolving and the content should reflect those changes. Decision-making, problem-solving, and working in teams are norms that are essential for an engineer to work in today's global engineering environment. Following the blended learning approach, Greenfield Coalition has adopted a unique way of developing and delivering content that enables engineers to acquire the needed competencies. Greenfield Coalition's blended learning approach, utilizing discovery and problem-solving strategies based in real world situations, has given students the opportunity to discover the links between theory and practice and learn the application of the theories within authentic conditions.

Acknowledgement

The Greenfield Coalition is partially supported by a Grant EEC-9630951 under the Engineering Education Coalitions Program at the National Science Foundation. Focus:HOPE, our industry and academic partners have contributed valuable resources to support the development of Greenfield.

REFERENCES

[1] Kroder, S. S, J. and Sachs, D. "Lessons in Launching Web-based Graduate Courses,' The Journal On-Line: Technological Horizons in Education. Vol. 25, Part. 10, (1998) pp66-69.

[2] Pelham, T M, "The Adaptability and Flexibility of eLearning", Hartford Business Journal, October 01, 2000.

[3] Gramoll, K. "An Internet Portal For Statics And Dynamics Engineering Courses", International Conference on Engineering Education, August 6 – 10, 2001, pp 3B1-1.

[4] Ahdell, Rolf, Gottorn, Anderson. "Games and simulation in workplace eLearning", Master Thesis Norwegian University of Science and Technology. 2001. [last access 14 March 16, 2003]. www.twitchspeed.com/site/download/thesis_final.pdf

[5] Denning, P. "Educating a New Engineer". Communications of the ACM, 35(12), (1992). p 83-97.

[6] Moore, Michael "Distance Education: A Systems View", Wadsworth Publishing Company, 1996 [last access 14 March 16, 2003]. http://www.cde.psu.edu/de/what_is_de.html#definition

[7] Ramos, F. Conde, A. Neves, L. Moriera, A. "Management of eLearning Environments: some Issues and Research Clues", Proceedings of the IASTED International Conference, Applied Informatics, Feb 2002.

[8] Frontend.com, "Why People can't Use eLearning". Available at the Infocenter Frontend web site, [last accessed on March 23, 2003]: http://infocentre.frontend.com/downloads/ Why_people_can't_use_eLearning.pdf

[9] Messy, J. "Quality and eLearning in Europe Survey report 2002, BIZ Media" (Last accessed on March 24, 2003) www.elearningage.co.uk/docs/qualitysummary.pdf

[10] Online Training Needs a New Course", Forrester Research Inc., Cambridge MA, USA. [Last accessed March 23, 2003] http://www.forrester.com

[11] Smallwood J, E. & Zargari, A. "The Development and Delivery of a Distance Learning (DL) Course in Industrial Technology", Journal of Industrial Technology, Vol. 16 No. 3 May – July 2000.

[12] Florman, S.C "The Existential Pleasures of Engineering" . New York: St. Martins Press. (1976).

[13] Kemper, J.D. "Engineers and Their Profession", (3rd Ed). New York: Holt, Rinehart & Winston. (1982).

[14] Williams, R. "Education for the Profession Formally Known as Engineering", The Chronicle of Higher Education The Chronicle Review, Vol 49 Issue 20 January 2003.

[15] Bandura, A. "Self-Efficacy: The Exercise of Control". New York: W.H. Freeman, (1997).

[16] Vygotsky, L.S. "Mind in Society". Cambridge, MA: Harvard University Press, (1978).

[17] Cross, K.P. "Adults as Learners". San Francisco: Jossey-Bass (1981).

[18] Rogers, C.R. & Freiberg, H.J. "Freedom to Learn" (3rd Ed). Columbus, OH: Merrill/Macmillan (1994).

[19] Jones, R. "Educational Technology for Quality Engineering Education".: American Society for Engineering Education. Washington, DC (1986).

[20] Salomon, G. "Communication and Education". Beverly Hills, CA: Sage. (1981).

[21] Mager, R. "Making Instruction Work. Belmont", CA: Lake Publishing Co. (1988).

[22] Rogers, C.R. "Freedom to Learn". Columbus, OH: Merrill. (1969).

[23] Schmidt K. E & Gallegos, A, "Distance Learning: Issues and Concerns of Distance Learners" Journal of Industrial Technology • Volume 17, Number 3 • May 2001 to July 2001.

[24] Falkenburg, D. "The Greenfield Coalition: Partnership For Change In Manufacturing Engineering And Technology Education", International Conference on Engineering Education, Oslo, Norway 2001.

[25] Gagne, R. "Instructional Technology Foundations". Hillsdale, NJ: Lawrence Erlbaum Assoc. (1987).

FIGURES AND TABLES

FIGURE. 1
ELEARNING CONTENT DOMAIN.

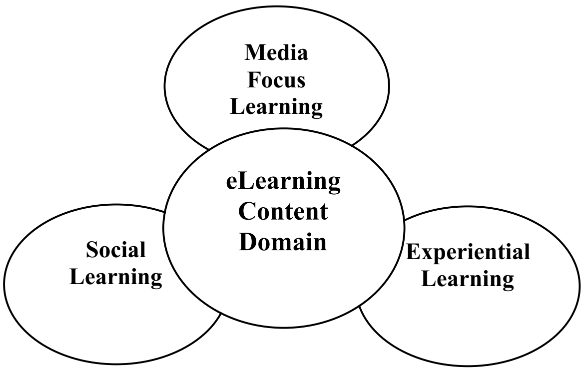

FIGURE. 2
LEARNING DOMAIN FOR ELEARNING CONTENT AND GREENFIELD COALITION PARADIGM.

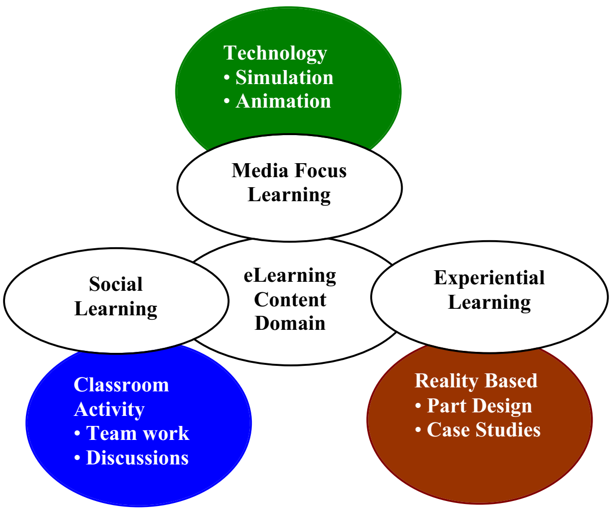

FIGURE. 3
MACHINING PROCESS AND PRODUCTION RATE ACTIVITY TOOL

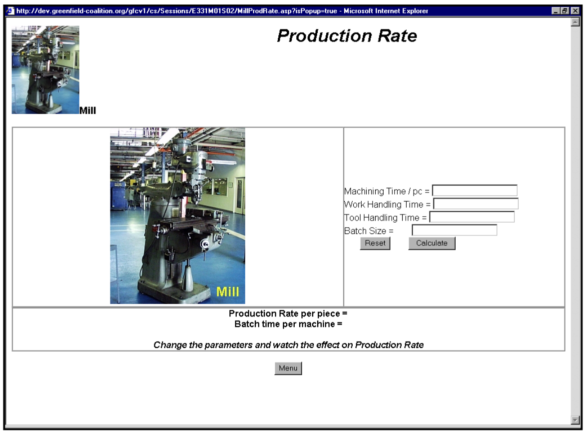

FIGURE. 4
ASSEMBLY AND PRODUCTION RATE TOOL

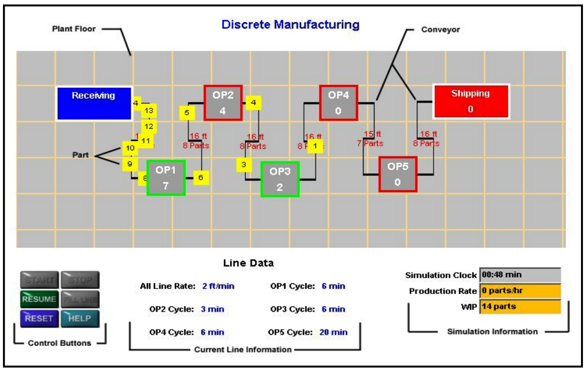

FIGURE. 5
CAPACITY AND RESOURCE ALLOCATION TOOL.