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Title: Operations Management Education Utilizing eLearning Techniques with Industry-University Collaboration

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Abstract

This paper describes activities in an operations management e-Learning course 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 operations management 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 pertinent 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 e-Learning materials are dependent upon the successful combination of real world content, technology and interactivity.

Specific course development examples are drawn from the Greenfield Coalition Learning System whose creation is partially sponsored by the National Science Foundation. The industry-university development team collaboration process explained in the paper uses videoconferencing to share applications such that the design review and the editing process can occur in real time. This includes dynamic motion examples. Team members create or manipulate dynamic objects that are integrated into the final work product. The flow of work is a parallel process, which preserves the benefits of face-to-face interactions. The paper also includes lessons learned from earlier course development activities. Course objectives and examples of course content are included.

Introduction

This paper describes an operations management e-Learning type course built upon three mutually supporting delivery modes to improve learning outcomes. The setting for this was the Greenfield Coalition, an NSF sponsored program located in Detroit, MI and one of its partner institutions, Lehigh University, located in Bethlehem, PA. Examples drawn from the instructional materials that were created are presented and described for each of the learning modes: classroom, web-based, and experiential. The evolution of the development process is explained. The foundation of the instructional design methodology was Gagne's nine external events of instruction. The process of applying this methodology became more effective by including an instructional designer on the work team and by using technology to share applications, edit materials in real time, and more rapidly cycle through revisions to achieve the final work product. Although the formal evaluation of the coursework is not complete, early anecdotal evidence suggests that this approach to teaching operations management course materials is effective.

Learning Environment

Activities in the operations management e-Learning course are organized in a structured framework. Courses are comprised of modules, and modules are comprised of sessions which in turn contain the individual course activities. This structure and the development process used to create the course are discussed in subsequent sections of this paper.

The structure of a typical session is depicted in Figure 1. The activities that are listed are keyed to indicate the presentation mode. The flying  indicates e-Learning, and the  indicates experiential learning. Classroom learning is not designated by a symbol. E-Learning is characterized by links to other web sites or other lessons within the system that have similar material or content. In the session shown in Figure 1, Activity 2 links to a slide show of an automotive transmission production facility. One of the photographs from that tour is shown in Figure 2. As indicated by the underlined text in Figure 1, several of the concepts in activity number one and the entire activity number two are shaded hyperlinks that take the user to the appropriate web page when the link is selected. The symbol at the start of the lesson is a hyperlink to an instructor's guide that provides guidance for the instructor and supplemental background information about the session. As is typical in hypertext applications, the mouse cursor changes shape when passing over the active links.

In another session shown in Figures 3, 4 and 5, the e-Learning activity changes from a virtual plant tour to an interactive spreadsheet type of exercise. The student must do an analysis and complete the table to illustrate the relationship between the component parts and the completed assembly.

The activity map in Figure 3 indicates three activities that must be completed in the session. First, students must read background material on the topic of material requirements planning. This introduces the data elements required to drive the process, and presents the fundamental algorithms used to calculate schedules.

Session 4 Lean Manufacturing & Value Stream Management

Activities

Activity 1: **Lean Manufacturing Reading**

- Familiarize yourself with the following concepts:
  - Potential Waste in Mass Production
  - Flexible Production System Measures
  - 5S of Workplace Organization
  - JIT/Kanban/Pull system principles
  - Four principles of lean manufacturing
- After reading about these concepts, you should be prepared to answer the following questions:
  - How are the following related: Lean Manufacturing, Just in Time (JIT), and Flexible Production Systems (FPS)?
  - What are the four principles that are used to guide lean manufacturing?
  - How is lean manufacturing different than agile manufacturing?

What principles can be applied to make an operation leaner?

Activity 2: **Virtual Walk Through a Production Facility**

Activity 3: **Classroom Design of Traffic Signal**

- Be prepared to participate in the following classroom activity:
  - Develop a production line to produce a traffic signal and apply lean principles to the design
  - Your instructor will provide further detail

Be prepared to participate in a discussion after the activity

Activity 4: **Lean Manufacturing Recap Discussion**

- Recap concepts based upon the following:
  - Guided reading questions
  - Types of waste
  - Measures of flexible production system
  - 5S of workplace organization
  - Virtual tour

Design of traffic signal

Figure 1. Typical organization of a session showing the breakdown into activities and indicating activities using e-Learning and experiential learning approaches.

Figure 2. Activity 2 tour of a transmission shop.

In the second activity, the students are provided a product structure, lead times and demands for finished products required over several planning periods as depicted in Figure 4. The students enter these data into a planning worksheet that facilitates the calculation of planned order releases for materials, components and subassemblies required to meet the production schedule. Partial results for this exercise are shown in Figure 5. The final activity in the session is a recap step involving additional readings and in-class review and discussion with the course instructor.

Session 2 **Material Requirements Planning**

Activities

Activity 1: **Material Requirement Planning Reading**

- Familiarize yourself with the following concepts:
  - Production Planning
  - Material Requirements Planning (MRP) inputs & outputs
  - Netting
  - Lead time
  - MRP II
- After reading about these concepts, you should be able to answer the following questions:
  - What are the possible effects of a master schedule that is improperly set either too high or too low?
  - Does MRP allow for minimum inventory level?

How could MRP concepts be applied to a fast food restaurant?

Activity 2: **Material Requirement Planning**

Activity 3: **Material Requirement Planning Recap**

- Recap concepts based on the following:
  - Guided reading questions
  - Responses from web component
  - Advantages and disadvantages of MRP
  - Classroom work to develop different schedules

Figure 3. Material Requirements Planning session structure.

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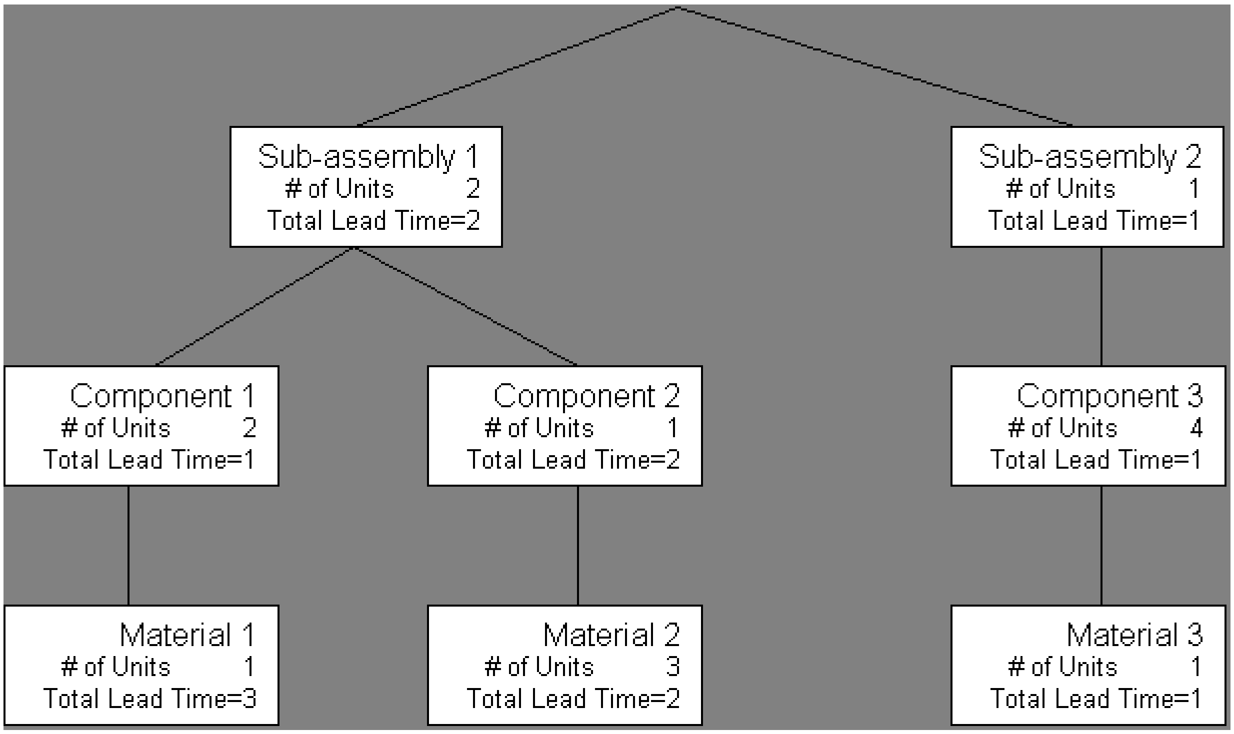
Material Requirement Planning Schedules

Consider the following product structure chart. Use your knowledge about MRP and the information given in the chart below to complete a Master Production Schedule (MPS).

Final Product	
# of Units	See Chart
Total Lead Time =	7



Period	8	9	10	11	12
Demand	6	11	8	15	9

Click here for schedule one spreadsheet

Questions

Figure 4. Diagram depicting the product structure, lead times and final product demands for MRP Activity 2.

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MRP Schedule Solution

Period		1	2	3	4	5	6	7	8	9	10	11	12
Item: **Final Product**													
Gross requirements									6	11	8	15	9
Scheduled receipts													
On hand	0												
Net requirements									6	11	8	15	9
Planned order releases								6	11	8	15	9	
Item: **Sub Assembly 1**													
Gross requirements								12	22	16	30	18	
Scheduled receipts													
On hand	2							2					
Net requirements								10	22	16	30	18	
Planned order releases						10	22	16	30	18			
Item: **Component 1**													
Gross requirements						20	44	32	60	36			
Scheduled receipts													
On hand	1					1							
Net requirements						19	44	32	60	36			
Planned order releases					19	44	32	60	36				
Item: **Material 1**													
Gross requirements					19	44	32	60	36				
Scheduled receipts													
On hand	0												
Net requirements					19	44	32	60	36				
Planned order releases		19	44	32	60	36							
Item: **Component 2**													
Gross requirements						10	22	16	30	18			
Scheduled receipts													
On hand	1					1							
Net requirements						9	22	16	30	18			
Planned order releases				9	22	16	30	18					
Item: **Material 2**													
Gross requirements				27	66	48	90	54					
Scheduled receipts													
On hand	5			5									
Net requirements				22	66	48	90	54					
Planned order releases		22	66	48	90	54							

Figure 5. A portion of the solution worksheet for MRP Activity 2.

Course Content and Focus

The course concentrates on the management of manufacturing systems in industrial settings and deals specifically with multiple operations management topics. In addition to those illustrated in this paper, the course deals with flexible manufacturing systems (FMS), process planning, single model assembly lines, group technology and cellular systems, just–in-time, value stream management, simulation and other related subjects. The terminal objective for the course and objectives for each of the modules are enumerated in Figure 6.

Multiple methods of presentation: web based, experiential, and classroom are used throughout all the sessions to improve the understanding and retention of the student. For example, the tour of the transmission shop includes various pointers, observation items and questions that the viewer should be aware of in order to participate in the follow up class discussion.

The typical session on MRP takes a different approach to problem solving. After reading appropriate material, the student is directed to examine the sample operation shown graphically in Figure 4. The student is then directed to fill in a blank worksheet similar to Figure 5. A hidden program goes through the worksheet and compares the student answers to the solution worksheet. If the student worksheet is incomplete or incorrect, the program informs the student that the answers were incorrect and where the incorrect answers are located. If the answers provided by the student are correct, a message is displayed indicating that fact. In this way, the MRP session model and spreadsheet dynamically interact with the student. It provides immediate feedback to the student eliminating delays common with traditional homework. In all sessions, there is a follow-up classroom discussion to emphasize the important content and deal with any questions that may not have been answered in the earlier parts of the session.

Terminal Objective
Upon the completion of this course series, the candidates will be able to design manufacturing systems and solve production problems through the application of advanced analysis tools and analyze the impact of new operational models on system management.
Module 1 Objectives
Upon completion of this module, the candidates will be able to • Quantify production capacity requirements of a manufacturing system considering production quantity, product variety, and product and part complexity; • Calculate basic performance attributes of manufacturing systems such as measures of production rate, capacity, and manufacturing lead-time; • Determine the number of workstations required to satisfy production schedules and the number of machines a worker can operate in a machine cluster; and Analyze a single model assembly line to calculate line parameters, including baseline worker requirements; then, recalculate worker requirements by applying line-balancing heuristics.
Module 2 Objectives
Upon completion of this module, the candidates will be able to • Analyze process data according to group technology principles and gage the benefits of cellular manufacturing systems through the application of machine cell design concepts; • Design a manufacturing cell through an analysis and identification of part family/work station clusters; • Assess the elements, applications, and benefits of Flexible Manufacturing Systems and identify techniques for the analysis of FMS designs; and • Apply the Bottleneck model to determine FMS performance measures. • Design a transfer line system based upon demand and product design; • Design an automated assembly system based upon a product's manufacturing requirements; and • Manage a manufacturing system through the implementation of e-manufacturing methodologies.
Module 3 Objectives
Upon completion of this module, the candidates will be able to • Develop a process plan based upon traditional or concurrent engineering principles; • Develop a master schedule using product attributes and system constraints through evaluating the interrelationships of the components within a material requirement planning system; • Calculate Just in Time metrics implemented within manufacturing systems and contrast push verses pull philosophies; • Implement lean manufacturing principles into product development; and Develop Monte Carlo simulation models and analyze their outputs to predict manufacturing and service performances.

Figure 6. Terminal objective for the course, and detailed objectives for each course module.

Background on the Development Process

The technologies available for both curriculum development and delivery have evolved rapidly over the past decade. Prior to the general availability of affordable videoconferencing systems, most curriculum development involved individual faculty efforts. Attempts at collaboration required the physical proximity of team members or the expense of travel for face-to-face development work. The alternative was to circulate draft materials among collaborators using more traditional means such as fax or overnight delivery services. The end product was typically paper-based or compiled in presentation format. Development times were long and the unit of production was large; generally, a complete course.

The introduction of videoconferencing techniques facilitated the process of collaboration. Particularly for geographically dispersed teams, this technology permitted more frequent collaborative sessions while preserving much of the dynamics of human interaction. The interplay of personalities and rapid exchange of ideas typical of face-to-face interactions, was largely preserved, and development time was reduced. Often however, the work product was largely the same. Instruction was still delivered, whether face-to-face or distanced, using a traditional static presentation format.

Recognition of this situation led to the next step which was the introduction of authorware type software and the related development process. The resulting products were computer-based and enabled several potential improvements. For example: 1) they were self-paced; 2) navigation support within large blocks of material was provided; 3) there were assessment capabilities; and

4) supplemental materials to assist students needing additional explanation of the material could be included. This process, however, introduced additional burdens on course development process. The most significant of these was the frequent need for professional programmers to encode the material, a need for course designers to create detailed specifications to instruct the programmers, and a large number of cycles for design review and editing. In addition, the end product was fixed, and difficult to modify incrementally or easily customize.

With respect to the approaches presented in this paper, a major goal was to permit the team within the videoconferencing framework to share applications such that the design review and the editing process could occur in real time. In addition, the use of an instructional designer during the early development phases would reduce the likelihood of designs which would be technically difficult or overly time consuming for programmers to execute. Team members could then create or manipulate static or dynamic objects that were easily integrated into the final work product. The flow of work changed from a serial to a parallel process while at the same time preserving the benefits of face-to-face interactions.

Several factors contributed to a major improvement in the productivity and efficiency of the course development process. Personal computer hardware and software capabilities advanced dramatically. Hardware processor speed, input/output capability and high-density storage capacity enabled the storage, manipulation and display of high quality multimedia objects. Software provided robust and user-friendly multimedia editing tools and the capability to integrate numerous multimedia streams into a seamless package with a sophisticated navigational framework. The creation of course materials occurred much more quickly and at lower cost as a result of these improvements.

The Development Process

For the example presented in this paper, the course development team consisted of an instructional designer, academic subject specialists from two universities, and industry subject experts. The collaborative sessions were typically two hours in length, meeting once a week. The videoconferencing collaboration took place at two facilities: The Enterprise Systems Center at Lehigh University in Bethlehem, PA (Figure 7) and The Center for Advanced Technology at Focus:HOPE in Detroit, MI (Figure 8). The course being developed, Manufacturing Systems II, was part of the curriculum of the Bachelor's degree program offered through the Greenfield Coalition and piloted at the Focus:HOPE Center for Advanced Technology. The course teaches the fundamental principles of manufacturing systems and associated operations management techniques.

Based on the Greenfield Coalition Learning Hierarchy shown in Figure 9, the course was broken down into modules, sessions and activities. At this early stage, the industry subject experts contributed contemporaneous best industry practice methods such as the use of TAKT time and value stream mapping. The various team members developed sessions based on their appropriate strengths and knowledge. The pedagogical approach was patterned after Robert Gagne's nine external events of instruction and their corresponding cognitive processes[1]. The value of this approach has been tested in practice and adopted as a standard for curriculum development within the Greenfield Coalition[2][3][4][5].

FIGURE 7.Greenfield Coalition team members at Lehigh University.

FIGURE 8. Greenfield Coalition team members at Focus:HOPE. Sohail Ahmed(l), Wayne State University academic subject specialist, Scott Matthews(c) Ford Motor Co. industry subject expert, and Nancy Baskin(r) Greenfield Coalition instructional designer

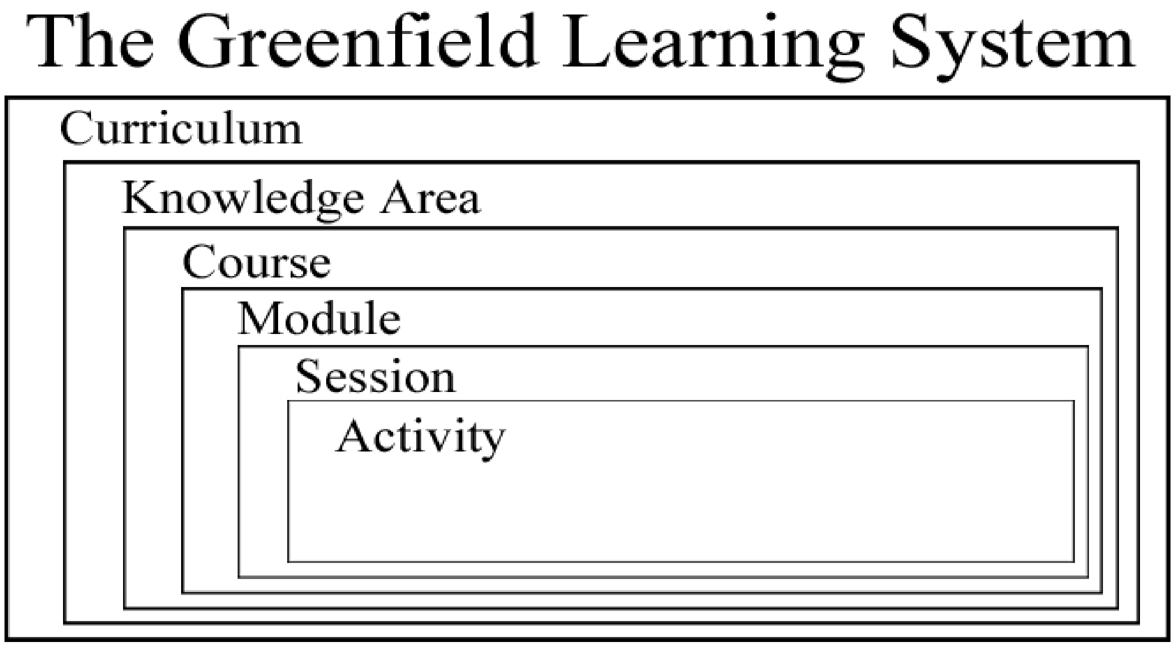

FIGURE 9. Greenfield Coalition learning hierarchy [2]

In the early stages of the process, as sessions were developed they were submitted via e-mail to the instructional designer. The weekly teleconferencing meetings were then used to review the progress of the team members and discuss any problems or difficulties. Early stumbling blocks included layout problems caused by unfamiliarity with the format and structure being used by the Greenfield Coalition. As the team became more familiar with the desired structure, other difficulties such as integrating the different application languages arose.

As all the developers became familiar with the process, standards, and structure of the course, the videoconferencing meetings became an instrument of real time editing and collaboration. Although real-time, direct, online sharing of applications was an objective of the group and was a feature provided by the VTEL System, this was not accomplished as originally conceived.

In order to get started immediately, application sharing was initially accomplished through the use of a desktop document camera. A laptop computer was simply placed in front of the camera and the image on the display screen was transmitted to the remote site. The type and location of the cameras at the Lehigh site made this an acceptable method of sharing information (Figure 10). Although its design was more suited to transmit hand drawn sketches and prepared slides or papers, it proved to be an adequate to the task of transferring information the Focus:HOPE site.

The location of ceiling lights made this more difficult at the Focus:HOPE site. Glare from the lights made the image unreadable. The later installation of a video projector at the Focus:HOPE site along with the location of the cameras made the use of a projector a preferable alternative because it eliminated glare as a factor (Figure 11). The projector method was not utilized at the Lehigh University site because the location of the projection screen was not entirely visible to either of the cameras.

The use of videoconferencing allowed review and modification of the sessions after they had been through the initial draft and rewrite. The academic specialists and industry experts used online editing to perform the necessary final revisions before the material was published to the web. At this point in the process, the instructional designer provided methodology discipline and managed the real-time editing process. Using the projector to display the work under consideration, team members quickly completed the online editing without the time delay that occurs using mail, fax, or electronic distribution to the reviewing parties. Online editing is shown in Figure 11.

FIGURE 10. Initial application sharing arrangement prior to the use of embedded system software

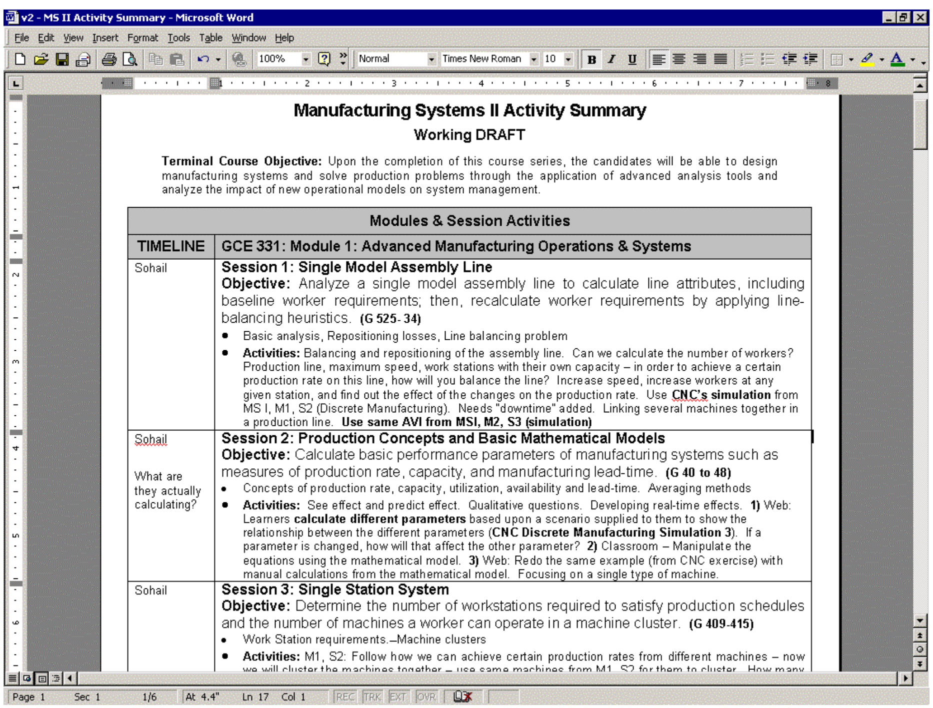

FIGURE 11. Improved application sharing arrangement

While stumbling blocks typically occur in any collaborative effort, the use of videoconferencing reduced the lag and response time required to resolve the problem by eliminating rework or conversions.

Equipment Used For Course Development

The videoconferencing equipment at the Lehigh University site included the following:

- Hardware**:** VTEL Enterprise Series Leadership Conferencing System®, model MM-1, including ELMO EV-400AF Visual Presenter
- Software: Microsoft Windows 95®, Microsoft Windows OFFICE 2000®, VTEL Appsview™ version 1.10

A diagram of the system elements is shown in Figure 12.

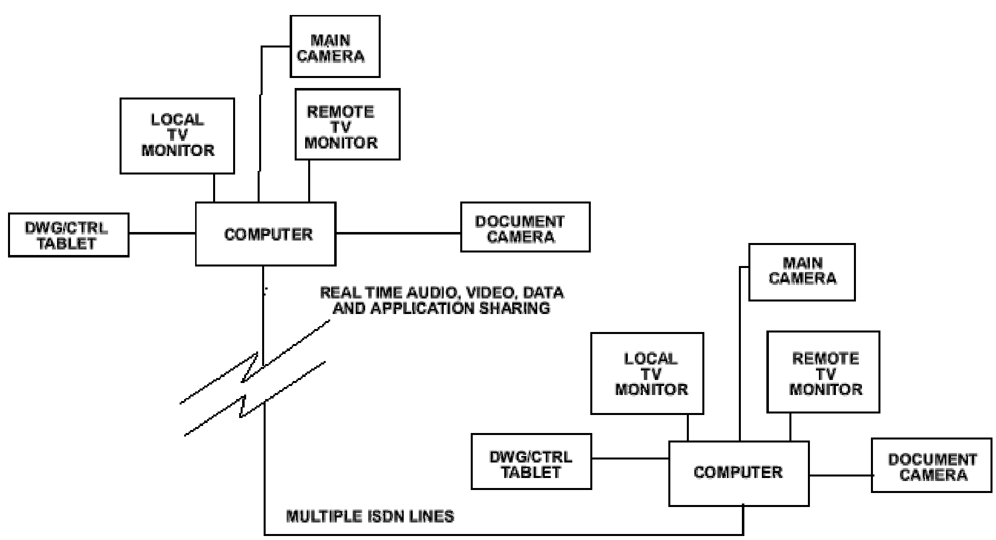

FIGURE 12. Block diagram of videoconferencing network

The diagram shows multiple ISDN lines for communication between sites. More recent versions use internet communications protocol and realize an improved picture quality.

Conclusions

The three presentation modes – classroom activities, e-Learning, and experiential learning – are effective in teaching manufacturing systems and operations management materials. Compared to traditional teaching methods, anecdotal evidence indicates that such materials are easier to understand and more interesting. The Gagne methodology is appropriate for the presentation of operations management topics.

The development process was improved. Real-time data sharing, application sharing, and editing accelerates work progress. Even where the technology is imperfect, the techniques developed represent a substantial improvement over traditional paper-based methods. The use of an instructional designer provides immediate feedback to the development team, avoiding ideas and concepts that are excessively difficult or expensive to implement using available technologies.

Acknowledgment

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References

[1] Gagne, R., Briggs, L., Wagner, W., *Principles of Instructional Design*, 4th Ed., 1992

[2] Falkenburg, D., "The Greenfield Coalition: Partnership for Change in Manufacturing Engineering and Technology Education," *Proceedings of the International Conference on Engineering Education*, August 2001

[3] Khasnabis, S., Ellis, R.D., Schuch-Miller, D., Liu, S.L., Santhanamurthy, R., Plonka, F., Falkenburg, D., "Web-Enhanced Tools for an Engineering Economics Course," *Proceeding of the 32nd ASEE/IEEE Frontiers in Education Conference*, Boston, MA, November 6-9, 2002.

[4] Ahmed, M.S., Baskin, N.L., Tonkay, G.L., Wittchen, A.G., Zimmers, Jr., E.W. "Web-Based Learning Activities in Manufacturing Systems," *Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition*, Montreal, Quebec, Canada, June 16-19,2002.

[5] Falkenburg, D., "E-Learning in the Greenfield Coalition," *Proceedings of the International Conference on Engineering Education*, Oslo, Norway, August 6-10, 2001.