AC 2009-2221: ENHANCEMENT OF NETWORK-BASED MANUFACTURING EDUCATION: A QUASI-WEB-BASED INSTRUCTION APPROACH

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Dr. Zhang graduated from Kansas State University with a PhD degree in Industrial Engineering. She teaches courses in reliability and maintainability, manufacturing system modeling, and tooling engineering. Her areas of technical expertise include nondestructive evaluation (NDE), manufacturing process control and optimization, and industrial engineering applications. She has a number of papers published in the international journals and conference proceedings. As a new woman faculty, after Dr. Zhang joined UTEP in fall 2006, she has participated in a NSF CCLI Phase II proposal and NSF Advance Program. Her previous experience in course enhancement and strong desire for teaching excellence will be significant contribution toward the success of the project.
Enhancement of Network Based Manufacturing Education: 
A Quasi-Web Based Instruction Approach

Abstract

The objective of the paper is to design, implement, and further enhance a set of network based manufacturing (NBM) courses on the topics of automation, production and advanced manufacturing within the established programs. The aforementioned courses constitute the foundation of what is commonly known as e-manufacturing systems, in which the remote monitoring, diagnosis and control of distributed manufacturing operations are the key characteristics. This paper aims at developing an effective learning model to facilitate student’s learning through a quasi-web based approach. The finding from the collected data provides an indication of how to effectively study this problem in further investigations. This paper forms the basis for solving many other similar problems that occur in manufacturing industries.

Introduction

The objective of this paper is to design, implement, and further enhance a set of network based manufacturing (NBM) courses on the topics of automation, production and micro-manufacturing within the established programs. The aforementioned courses constitute the foundation of what is commonly known as e-manufacturing systems, in which the remote monitoring, diagnosis and control of distributed manufacturing operations are the key characteristics. With the trend of rapid globalization across almost all types of manufacturing industries, it is foreseen that the network based manufacturing will become a significant activity in coming years. According to literatures 1-6, the NBM is one of the fast growing businesses in the manufacturing sector. A distinguishing characteristic on the delivery of the curriculum will be student involvement in “hands-on” laboratory activities and experiences. Furthermore, graduates from the program will be well-prepared with high-tech skills in the areas of automation, production and micro-manufacturing technology. It is expected that nationally this curriculum reform will become a national model of teaching network based manufacturing technology and management, while locally it will provide much of the needed manufacturing professionals for the industries.

Background

Globalization has changed the landscape of manufacturing industry. Many manufacturing activities are performed at geographically dispersed locations, while coordinated and integrated by Internet-Based communication and control software. Hence, topics on distributed manufacturing are of a lot of interests in both academia and the business world. The current state-of-the-art practice includes the multinational engineering teams for product design and the global business coordination, such as supply chain management. We foresee, however, that with the advance of automation and sensing technology, integration of physical manufacturing processes into the global business and engineering functions will be the next stage of the foregoing manufacturing evolution.
Development of e-Manufacturing Lab for Network Based Manufacturing Education

School XXXX has recognized the strategic importance of the new program to the manufacturing industries, which has materialized through a strong support in resources. This lab is the synergistic combination of manufacturing engineering, computer, information technology, control systems as well as Internet-based, advanced tools for collaborative product design, remote process monitoring & control, embedded functionality, and built-in intelligence. One critical attribute of the lab development is to excite and expose the students about e-Manufacturing through hands-on projects and summer workshops and seminars, hence encouraging them to take various courses covering automation, production and advanced-manufacturing that are integrated with information networks. In addition, the lab will be utilized for engineering problem solving courses aligned with current industry projects, where students work as engineering teams and simulate the functioning of a real world manufacturing enterprise. The lab will employ graduate students to help develop experimental setups along with student lab manuals and instructors’ notes. An overall architecture of the Network Based Manufacturing Laboratory (NBML) at school XXXX is depicted in Figure 1.

Figure 1. An overall architecture of the Network Based Manufacturing Laboratory (NBML)
Problem Description

The ABET Engineering Criteria states the engineering students should be able to communicate effectively, function on multi-disciplinary teams and use the techniques, skills and modern engineering tools necessary for engineering practice. This requires the development of creative education model to promote team-based collaborative learning focused on engineering projects, establish close ties among different schools and programs, and promote interdisciplinary education. Yet current education models are primarily based on the learning in the classroom with a clear delineation between disciplines. Students attend the lectures and are evaluated through homework problems, class projects and exams. Even though the importance of team work has been stressed over the years for the successful engineering career development, the extent of implementation is limited to the team projects in the classroom. Many engineering/business courses are pure lecture-based, and do not usually contain components that help student to boost their communication skills within the framework of engineering problems. The limited exposure to this critical success skill has resulted in isolated learning experience. Students lack the broad understanding in other areas of study and oftentimes speaking different languages between the disciplines. Many industries (i.e., automotive, aerospace, electronics, etc.) are complaining about the lack of preparation future engineers are receiving in colleges and universities. The industries pointed out that there exists a huge, yet common deficiency among the engineering students, asking that students should learn how to communicate effectively. This is aligned with the exponential growth of advanced, sophisticated technologies that resulted in an increasing demand for engineers. The report prepared by the Society of Manufacturing Engineers (SME) listed 14 competency gaps that engineering graduates are lacking, which includes oral communications, listening, teamwork, working effectively with others, quality, product/process design, etc. To address this concern, there is a need to develop and incorporate an innovative education model to engineering curriculum to ensure that engineering graduates are equipped with appropriate knowledge and necessary skills in active learning, communication and information seeking.

What is giving added challenges to such education model is the emerging distributed operations in industries. In recent years, the centralized companies of the past have been replaced by geographically dispersed, remotely located companies collaborating on a common project. The technical advances, especially the Internet, have been the major driving force behind this trend. Surprisingly, the full potential of these technologies are not currently used in the classroom settings. There is no comprehensive education model fully integrating available Internet technologies into classroom with an emphasis on the improvement of students’ skills in information seeking and communication. In most cases, it is limited to the on-line course delivery, emails and e-bulletin board between students and instructors. Therefore, the authors have implemented a quasi-web based approach to explore the use of Internet for active learning and information seeking skills enhancement in engineering curriculum.
Proposed Solution Approach

The term “Network Based Manufacturing (NBM)” refers to the information technology based principle, modeling approaches and computing networks, used to design products with built-in intelligence. According to the Report of the NSF subcommittee on Manufacturing Infrastructure, to enable the Nation’s Manufacturing Capability, “next generation manufacturing equipment will require the integration of fast manufacturing architecture, intelligent controllers, intelligent sensors and actuators, and innovative machining and tooling concepts”. Network based manufacturing through information and communication technologies are key elements to deploy real-time control of production processes in a global manufacturing enterprise. The role of communication vehicles such as Internet/Intranet in the creation of supply chain management has been recognized.

The implementation of Network Based Technologies in school XXXX will involve three major steps resulting into eight (8) courses modules associated with Automation, Production and Micro-manufacturing technologies. All five course modules will be delivered through implementing quasi-web based approach to improve learning effectiveness. The first step requires restructuring the current courses AA-0001 Industrial System Simulation and AA-0002 Statistics Quality Control and Reliability. The second step will involve the development of two new advanced network based manufacturing technology courses: AA-0003 Advanced Micro-Manufacturing and AA-0004/BB-0001 Advanced Automation & Computer-Integrated Manufacturing. The third step will involve restructuring the current course BB-0002 Production Planning and Control and developing one new course BB-0003 Scheduling of Automated Manufacturing Systems. These courses, of interdisciplinary nature and their associated hands-on laboratory experience, will become capstone courses, which will include trainings on hardware, software, term projects and, most importantly, NBM practice.

Generation of Course Modules and Courses

Below, the conceptual framework of module-based course development through the quasi-web based approach is illustrated.

Course Modules

1. Simulation for Global & Micro Manufacturing Module
   - Identify simulation and engineering tool integration requirements from hands-on experience with software tools, interactions with users and vendors, and industry road-mapping activities.
   - Capture relevant definitions, theory, algorithms, and data models as part of the science of manufacturing system integration.
   - Develop draft interface specifications of production scheduling, layout, machine modeling, machining and assembly process plans using the IMES methodology to advance the near term interoperability of engineering, simulation, and production management applications.
2. Intelligent Diagnosis & Prognosis Module
- Develop technologies to streamline and automate fault diagnosis and prognosis in intelligent maintenance systems.
- Develop algorithms and techniques to provide the necessary basics linking condition monitoring technology with asset management systems. The reliance on human intervention and interpretation to make diagnostics/prognostics will decrease as these activities are quantified with accuracy and reliability.
- Determine the safe life of equipment and drive the intelligent maintenance system by concentrating in data processing and data fusion/mining, intelligent diagnosis, and residual/service life prediction.

3. Micro Machining Module
- Micro machining, or miniature machining, refers to the machining of very small parts. The most common applications of micro machining are for the medical and electronics industries. Parts that are produced by micro-machining are typically so small that must be inspected using a microscope. Micromachining is typically performed by machine shops that specialize in the machining of miniature parts to precise tolerances.

4. Micro Assembly Module
- Introduction to Microfabrication technologies and processes
- Physics at the micro-and nano-scales
- Tools and tricks of the trade (instrumentation, etc)
- Brief introduction to assembly at the macro-scale
- Microrobotics (mobile and manipulator)
- Robotic assembly at the micro- and nano-scales

5. Measurement System Module
- Measurement Systems Analysis examines the nature of measurement systems and the fundamental analyses used to examine them.
- Understand concepts in the fundamental analysis of a measurement system
- Identify methods of analyzing variation error in measurement results studies
- Perform a gauge R&R study
- Examine measurement results with graphical analysis

6. Agile & Intelligent System for Scheduling & Control Module
- Dynamic scheduling: dynamic adaptation of the current schedule in the presence of unexpected events (machine breakdown, operation lateness, changing on order priority, etc.);
- Agile adaptation: flexible adaptation of the whole production structure according to given business process requirements.

7. Intelligent Decision Support Module
- Improve decision making ability of managers by allowing more or better decisions within constraints of cognitive, time and economic limits.
- Increase productivity of decision makers.
• Supplement one or more of a decision maker’s abilities. (i.e. knowledge collection, formulation, analysis knowledge derivation and problem recognition).
• Facilitate one or more of the decision-making phases (intelligence, design, choice).
• Facilitate problem solving flows.
• Aid decision maker in addressing unstructured or semi-structured decisions.
• Enhance a decision maker’s knowledge management competence, supplementing human knowledge management (KM) skills with computer-based KM capabilities.

8. Medical Manufacturing Module
• Dynamic scanning technology can help manufacturing engineers solve certain high-volume metrology problems.
• Micromanufacturing equipment development.
• Measuring Systems.
• Basic research into the micro cutting process
• Practical Products.
Contemporary Issues Related to Network Based Manufacturing

Module Pool

1. Simulation for Global & Micro Manufacturing Module
2. Intelligent Diagnosis & Prognosis Module
3. Micro Machining Module
4. Micro Assembly Module
5. Measurement System Module
6. Agile & Intelligent System for Scheduling & Control Module
7. Intelligent Decision Support Module
8. Medical Manufacturing Module

Course Development

1. Simulation for Global & Micro Manufacturing Module
2. Intelligent Diagnosis & Prognosis Module
3. Micro Machining Module
4. Micro Assembly Module
5. Measurement System Module
6. Agile & Intelligent System for Scheduling & Control Module
7. Intelligent Decision Support Module
8. Medical Manufacturing Module

Quasi Web Based Delivery Mechanism

1. Synchronized: Face to Face Lectures (p%)
2. Asynchronized: Audio/Video Embedded in Power Point Slides (1-P)%

Summer workshop/Seminar
At the e-Manufacturing Lab at School XXXX

Figure 2. The conceptual framework of module-based course development through the quasi-web based approach

Quasi-Web Based Approach for Effective Learning

The introduction of Web-based technologies during the second half of the 1990s has revolutionized the way many higher education institutions serve students. There are a number of reasons which initially drive individual institutions to consider Web-based distance-learning programs. These reasons include: (1) a means to capture market share and expand their reach to new markets; (2) pressure from boards of trustees, and
emphasis on a community and working adult service mission; (3) the desire to explore new pedagogical strategies and techniques (EDUCAUSE Center for Applied Research). The proposed quasi Web-based approach (QWBA) aims at taking advantages of the third reason, i.e., pedagogical strategies and techniques, to improve students’ learning.

Similar to the CD-ROM training programs, asynchronous Web-based programs are self-paced, highly interactive, results in increased retention rates, and has reduced costs associated with student travel to an instructor-led workshop. In addition, Web-based programs allow for easy access to the content and requires no distribution of physical materials. This feature translates into the following specific benefits:

- **Access is available anytime, anywhere, around the globe.**
- **Per-student equipment costs are affordable.** Almost any computer today equipped with a modem and free browser software can access the Internet or a private Intranet.
- **Student tracking is made easy.** Because students complete their training while they are connected to the network, it is easy to implement powerful student-tracking systems.
- **Possible "learning object" architecture supports on demand, personalized learning.** Students can access these objects through pre-defined learning paths, use skill assessments to generate personal study plans, or employ search engines to find exact topics.
- **Content is easily updated.** In today’s fast-paced business environment, training programs frequently change.

Despite these potential benefits, empirical studies typically have failed to find statistically significant differences between Web-based and face-to-face (FTF) course performance. The major drawback, when compared to synchronous FTF instruction, is the lack of human contact, which greatly impacts learning. While students can use their Web connection to e-mail their instructors or post comments on message boards, FTF classroom real-time interaction between instructor and students are still superior.

Indeed, it is found that students believed they learn more through FTF, even though their course performance was no different from the online students. Therefore, we propose QWBA to take the advantages of both FTF and Web-based technologies to maximize learning effectiveness. Here, synchronous instruction means in class FTF lecture while asynchronous instruction means web-based lecture which includes power point slides embedded with audio and video. In QWBA, the instructor is able to determine how many percent in synchronous/asynchronous instruction.
Comparison of the Conventional Approach and the Quasi-Web Based Approach for Effective Learning

School XXXX has implemented comparison of the conventional approach and the quasi-web based approach for effective learning. Course AA-0001 has been used to report the findings from this comparison. Basically, students have been separated into two groups: (1) Experimental group and (2) Control group. The experimental group is using the quasi-web based approach while the control group is using a face to face instruction approach.

Table 1. Analytical results between the experimental group and control group using Course AA-0001

<table>
<thead>
<tr>
<th></th>
<th>Motivation to learn</th>
<th>Cognitive Fatigue</th>
<th>Overall Learning Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental group (N=21)</td>
<td>4.5</td>
<td>3.9</td>
<td>4.7</td>
</tr>
<tr>
<td>Control Group (N=21)</td>
<td>3.7</td>
<td>4.0</td>
<td>3.6</td>
</tr>
<tr>
<td>Test Statistics</td>
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<td>Not Different</td>
<td>Significantly Different</td>
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</table>

Note: Evaluation using 1-5 scale

Conclusions

This paper presents a framework for developing a quasi-web based instruction approach for student effective learning. Particularly, the proposed approach is able to enhance Network Based Manufacturing (NBM) education according the pilot data. The finding from the collected data provides an indication of how to effectively study this problem in further investigations. This paper forms the basis for solving many other similar problems that occur in manufacturing industries.

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