DISTANCE LEARNING IN MANUFACTURING SYSTEMS: WHY AND HOW?

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Abstract: *The article presents the needed for changes in higher education in manufacturing, and why distance learning is the direction to go. The reasons for which distance learning is appropriate and needed in this education field are presented. Aspects specific to distance learning in manufacturing are then discussed: globalization, concurrent engineering, and online laboratory teaching. Two examples of online teaching for lab experiences are discussed, the MIT iLabs project and the Drexel University Applied Engineering Technology Program NSF grant. Various online programs for manufacturing are presented and how grants can be obtained.*

Keywords: Distance Learning, E-Learning, manufacturing education, globalization, laboratory teaching

Introduction

Information technology can be used to create learning communities across time and distance. It can access, display, store, and manipulate unfathomable amounts of information: text, images, video, and sound. It can provide design tools and sophisticated simulations. Numerous studies have been made about modifying engineering and specifically manufacturing engineering education in the US to keep pace with the economic, technological, and social changes of the 21st century. An interesting address was made at the National Academy of Education (NAE), October 14-15, 2003, by Charles M. Vest, President Emeritus of Massachusetts Institute of Technology, and NAE member. The emphasis of his talk is about how engineering educators must tap into (undergraduate/ freshmen) students' passion, curiosity, engagement and dreams to educate engineers for 2020 and beyond. He talks about the fact that the next generation will live in the most exciting period in human history for service and engineering, offering both a unique opportunities and challenges. "Exponential advances in knowledge, instrumentation, communication, and computational capabilities have created mind-boggling possibilities, and students are cutting across traditional disciplinary boundaries in unprecedented ways." (Vest, 2006)

For more information about the state of engineering one should consult the National Science Foundation's Division of Science Resources Statistics (SRS) which analyses and publishes data about the national (US) science and engineering resources. (NSF, 2008)

"Gerard O'Neil of Princeton made a study of predictions of the future and found one simple constant—we always underestimate the rate of technological change and overestimate the rate of social change (O'Neil, 1981). That is an important lesson for engineering educators…," says Charles M. Vest. (Vest, 2006) To take into consideration all the factors one needs to analyze and modify according the manufacturing curriculum and method of teaching. (Vest, 2006)

1 Why Distance Learning in Manufacturing?

The Distance Learning Definition is given by the US Distance Learning Association as: The acquisition of knowledge and skills through mediated information and instruction, encompassing all technologies and other forms of learning at a distance. There are numerous reasons for which we need to use Distance Learning in Manufacturing as presented in Figure 1.

1.1 Delivery and Pedagogy

Manufacturing education involves three main aspects which need to be delivered: theory/concepts, covered in lectures; hands-on experience, obtained in a lab environment, and real industry experiences and business knowledge, obtained through simulation, virtual enterprise environment, internships, joint academia-industry projects, and sharing of industry/business experience via long distance presentations and training.

All elements of distance learning in general are of interest in distance learning in manufacturing, and there is a vast literature on this topic. The only aspects of distance learning which we are going to mention in this article are those that are specific to manufacturing, i.e., distance learning environments for globalization, concurrent engineering team work, and lab experience.

Growing population of working students:
       Students have to divide time between work and studies
       Students have to travel long hours to a university campus
       The price of oil is becoming prohibitive for commuting
Globalization
       Engineering work is done in multi-national teams
       Students of manufacturing must get a multi-culture understanding
       Manufacturing uses Concurrent Engineering for collaboration at a distance
         Transfer of product, process and service data between distant geographic locations
Advances in IT
       Makes communication and data transmission at a distance possible
           (large files can be transmitted, video conferencing is viable)
       Working on Internet is the direction in Manufacturing
          Digital business (or e-business)
          Extended enterprise
          Extended product
       Distance Learning is the direction in Education
          Sharing knowledge from experts from industry
          Sharing Professors among universities
          Forming multidisciplinary, multi-cultural teams
The MTV generation, Generation X, and beyond which require to provide deep learning through instant gratification. "It sounds oxymoronic to me, but it seems to be happening! (Vest , 2006)"
The two frontiers of engineering - scale and complexity (Vest , 2006):
   -   the frontier dealing with smaller and smaller spatial scales and faster and faster time scales - the bio/nano/info world
   -   the frontier dealing with larger and larger systems of great complexity and, generally, of great importance to society: the world of energy, environment, food, manufacturing, product development, logistics, and communications
New important manufacturing considerations/needs:
   -   sustainability*
   -   business realities integration
   -   reverse engineering
   -   ecological manufacturing
   -   new systems engineering needed for large complex systems

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    ***Sustainability** can be defined as humanity's investment in a system of living, projected to be viable on an ongoing basis that provides quality of life for all individuals of sentient species and preserves natural ecosystems. Sustainability in its simplest form describes a characteristic of a process or state that can be maintained at a certain level indefinitely.(Sustainability – Wikipedia, 2008)

Figure 1. Rationale for Distance Learning in Manufacturing

1.2 Global Education for Manufacturing (Gardiner, 2001)

An international curriculum development project called "Global Education for Manufacturing (GEM} has been established by the Intelligent Manufacturing Systems (IMS) initiative with the objective of establishing graduate level curriculum framework capable of serving the global industrial manufacturing community. Digital business (or e-business) affords a radical new way of operating involving the advanced use of information and communication technology in every link of the supply chain. The concept of "extended products" appeared, implying taking a life time support perspective, including all services to support the product in addition to manufacturing it, and then retirement. The growth of information technology (IT) has accelerated a shift from the simple exchange of "cash" for products or services to entire manufacturing or commercial systems that market solutions enabling customer success, providing experiences and building continuing relationships. All of these factors together with the new global imperatives mandate the development of new curricula in manufacturing engineering. The project needed:

- Working with digital tools for communication
- Working in a multicultural environment
- Working in interdisciplinary, multi-skill teams
- Sharing work tasks on a global and around the clock basis
- Working in a visual environment

The Intelligent Manufacturing Systems (IMS) International Steering Council pointed to the need for a global education system in Intelligent Manufacturing Systems. Prof. Danielmeyer organized an expert meeting in Zurich on October 11th 1999 to discuss this. The recommendation was for a curriculum covering both manufacturing technology and manufacturing business – a Master degree in Manufacturing Strategy.

The development of the curriculum aims to include the following guiding principles:

- Provide a learning environment rather than a teaching environment
- On-going industry involvement focus on industrial needs and projects
- Equip students to serve in the new economy and to be change agents
- Recognize degree program structures appropriate to each region and country based on industry needs
- Establish linkages to IMS projects for collaboration, expertise and case work
- Ensure a viable business plan that shows sustainability and viability beyond the conclusion of the IMS project (Gardiner, 2001)

1.3 Concurrent Engineering and E-learning (Culler and Pérez García, 2004)

An educational project titled "E-Engineering" unites teams of students and professors from mechanical and industrial engineering departments at different universities to apply both E-Learning and Concurrent Engineering concepts to the cycle of new product development. Four universities have come together to design an experience which educates students about interdisciplinary team building, virtual work groups and international standards by creating an environment of true Collaborative Engineering. Teams were composed of students from three institutions; a conceptual design group, a prototype development group and an industrial production group. Product ideas were based on simplifying computer interaction for the disabled. The project demonstrated the complexity of the entire "art-to-part" process and exposed obstacles and cultural differences that teams had to overcome. The idea was conceived at the University of Vigo (UVigo) in Spain in 2002 and the project began in January, 2003 with three other participants; the Monterrey Institute of Technology (ITESM) in Mexico, the Costa Rica Institute of Technology (ITCR), and the Polytechnic Institute (ISPJAE) in Cuba. The experience is oriented towards unifying the needs of future professional engineers, combining collaborative, interdisciplinary work assignments with the use of information technologies, thus permitting students to enhance their education using real problems and a global approach.

This educational project is based Project Based Learning (PBL) whose philosophy is that students study concepts and learn methods by developing a specific application. Professors used PBL as the basis for defining common goals and guiding the E-Engineering effort. The exchange of information was accomplished using e-mail, ftp, various video conferencing programs, and the network REDIRIS. One program used was VRVS, a freeware provided by California Berkeley that allows multiple participants to interact with both video and audio. Several CAD/CAM systems were used. The conceptual design of products took pace in Mexico City with ProEngineer and Solid Edge, the prototype development in Spain with Catia and MasterCAM and the production planning in Costa Rica with SolidWorks and EdgeCAM. Students experimented with a variety of standards (ANSI, ISO, BSI, DIN, GT, ISO, DXF and DWG, IGES and STEP.)

1.4   Distance Learning for lab experiences

1.4.1   MIT iLabs Project (MIT iLabs, 2005 & MIT iLabs Challenge 2008)

Microsoft has funded, through the iCampus Project at MIT, a three year effort to explore the potential educational value of Internet accessible laboratories (*The iLabs Project*). The Project has moved from a wide sampling of potential labs and experiments to a more focused effort to develop a shared software infrastructure. The main goal was to make labs accessible to *students* first, then to faculty colleagues or industrial partners by integrating Internet accessible labs as smoothly as possible into students' educational experience. A priority of the project was that the participation of major lab equipment and software vendors (e.g., Agilent, National Instruments) to provide *Internet-ready* equipment and software. Internet accessible labs would encourage cross-institution cooperation. One can easily imagine students at one university using a laboratory made accessible by a second university. Schools or universities may decide to share the cost of an expensive laboratory and physically establish it at a convenient location. One can also imagine government participation that would offer limited access to national laboratories or facilities like the International Space Station. In time, as online labs proliferate, a faculty member or a student could locate an online lab that offers a particular experiment or technology.

These potential uses require that the software architecture separates lab users from lab providers. It also suggests that the architecture should support priorities of use, and eventually distributed resource accounting. For example, a particular MIT laboratory might decide to offer 10% of all access to students at Stanford and 20% of night access to a consortium of universities funded under an NSF initiative.

Three types of laboratory experiments, requiring different software architecture were distinguished:

- a batched experiment, the student specifies all parameters that govern the execution of the experiment before the experiment starts. The MIT Microelectronics WebLab (weblab.mit.edu) provides an excellent example.
- a sensor experiment, the student usually can not specify any parameters although he/she may be able to select the particular sensor data that he/she wishes to receive. Running the experiment consists of subscribing to real time sensor data, usually presented in a graphical user interface such as a virtual strip chart. This category of experiment is currently well represented at MIT by a flagpole instrumented with accelerometers that stream continuous data (flagpole.mit.edu).
- an interactive experiment, the student typically sets a series of parameters, initiates the experiment, and then monitors the experiment's course, changing control parameters as necessary. The Internet accessible heat exchanger at MIT (heatex.mit.edu) provides a good example of this type of experiment.

The goal in the first phase is to develop a shared architecture to support batched experiments that cross campus boundaries. Instead of employing a number of fine-grained services we have designed an architecture that more closely resembles three-tier web architecture.

1. The first tier is the student's client application that either runs as an applet or as a downloaded application on the student's workstation.
2. The middle tier, called the Service Broker, will usually reside on a server on the student's campus. It will be backed by a standard relational database such as SQL Server or Oracle. The student's client communicates solely with the Service Broker, which forwards experiment specifications to the final third tier.
3. This third tier is the Lab Server itself, which executes the specified experiments and notifies the Service Broker when the results are ready to be retrieved.
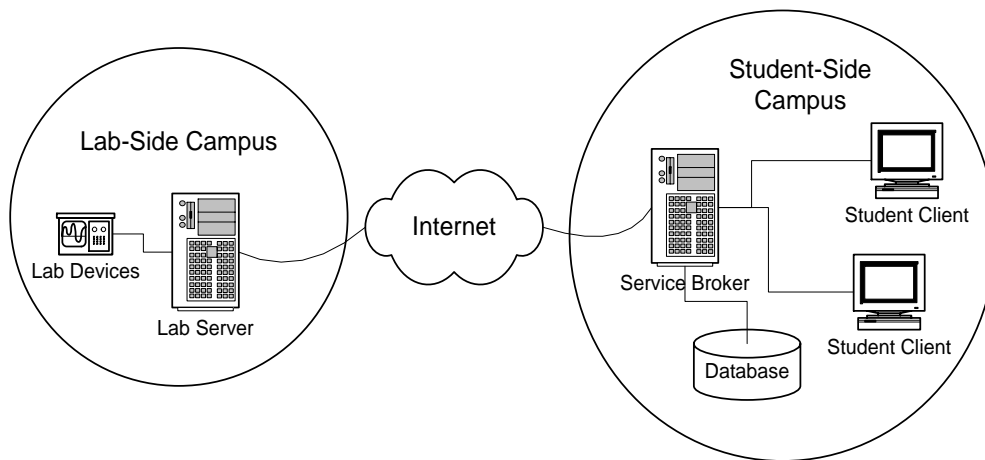
The overall architecture is shown in figure 2.

Figure 2. The MIT iLabs overall scheme. (MIT iLabs Challenge 2008)

1.4.2 Drexel University (Chiou, Kwon, Rauniar, and Sosa, 2006)

Drexel University's Applied Engineering Technology Program received an NSF grant to develop a series of laboratory courses in the area of internet based robotics and automation in manufacturing. The development efforts include industrial partnership with Yamaha Robotics, restructured and advanced courses in applied engineering program curriculum, and laboratory activities integrated with network technologies. The instructional materials for Internet based robotics and automation education utilized Robotics and Mechatronics lab as the experiments of choice. The program is building a network e-robotic and e-automation system towards real-world applications so that Internet users, such as students, can control the industrial robots in a dynamic environment remotely from any place in the world. The application-oriented curriculum, which is validated by the industry, has been developed with the goal of producing graduates ready to work in engineering technology. Internet-based techniques are used to allow the remotely situated students to program, control, and monitor the robotic operations through the Internet using the Windows-based graphical user interface.

This also allows the integration of robots and automation into the information networks and easy access through the Internet for design and manufacturing. A new learning technology was developed through the lab development for teaching of the remote monitoring/control of robots and programmable logic controllers (PLCs) and to effectively deliver internet based robotics and automation education through the Internet. The web-based control architecture for this program is shown in figure 3.
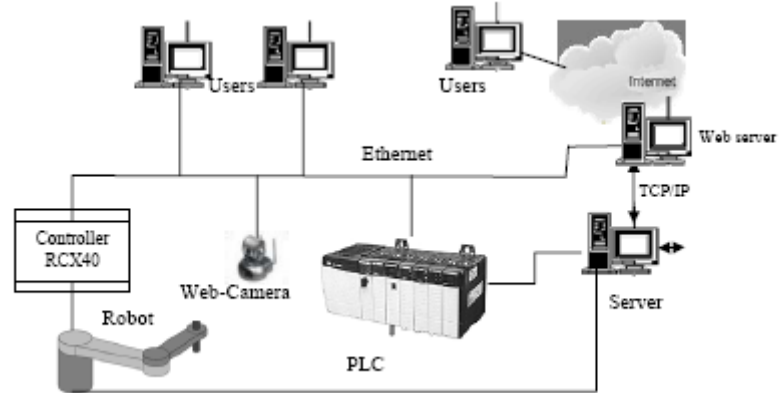
Figure 3. Drexel University's Web-based control architecture for delivering
internet-based robotics and automation education through the Internet.
(Chiou, Kwon, Rauniar, and Sosa, 2006)

This laboratory development component in the NSF project deals with integrating various AET (applied engineering technology) tools such as robots, pneumatic actuators, sensors, web-cameras, conveyors, programmable logic controllers (PLCs) and use Internet to connect these cross-platform systems. Visual Basic.Net has been used to create a graphic user interface (GUI) for performing offline analysis and to interact remotely with the system. All the devices, such as robot, web-camera, PLC, are connected to Ethernet enabling users (students) to operate/control the equipment remotely.

2 Universities with Online Manufacturing Engineering Degree Programs

(WorldwideLearn Manufacturing, 2008)

There are numerous programs in the US teaching on line, and many have started to teach manufacturing in this mode. We will only mention a few:

2.1 Boston University

Boston University's Master of Science in Manufacturing Engineering is delivered using videoconferencing technology. Students have the option of focusing their coursework in one of three concentration areas:

- Product Innovation and Management
- Manufacturing Operations Management
- Manufacturing Systems and Operations Research

2.2 Kettering University

Kettering University offers a Master of Science in Manufacturing Engineering through distance education. The curriculum emphasizes knowledge and skills needed to perform engineering functions in modern industry. Designed for the working professional, Kettering University's Masters Degree Programs are offered off campus through distance learning, as well as on campus at Kettering University. The convenience, flexibility, and portability of distance learning makes Kettering University's graduate programs available virtually anywhere in the world through DVD, CD-ROM, videotape, online video-streaming, and through Blackboard. Kettering University's distance learning graduate programs are available at more than 130 Learning Centers in North America, Europe and Asia. A Learning Center is a virtual campus that is usually located at a company worksite.

2.3 Rensselaer Polytechnic Institute

Rensselaer Polytechnic Institute offers a MS in Engineering Science with a Concentration in Manufacturing Systems Engineering through distance education. The program combines manufacturing

courses from the Schools of Engineering, Science, and Management. MS students follow a core of required courses in manufacturing and may specialize in one of two concentrations: Reliability or Information Science.

2.4   SME Education Foundation Grants (SME Foundation, 2008 & Dauch – SME, 2005)

In the June 2006 issue of the SME magazine, Manufacturing Engineering, the SME Speaks section, Richard E. Dauch. D, Co-founder, Chairman of the Board, and CEO of American Axle & Manufacturing, Detroit, MI, presents his ideas on "Preparing Tomorrow's Manufacturing Workforce." Dauch has a strong commitment to manufacturing engineering education. He has personally invested in educational endeavors, such as the Dauch Center for the Management of Manufacturing Enterprises at Purdue University (West Lafayette, IN). The company he co-founded in 1994, AAM, one of the top 40 automotive suppliers in the world partners with key colleges and universities to administer educational grants and provide instructors and training materials. While most of the training occurs on-site at AAM facilities, the colleges also supply off-site alternatives for larger training classes and seminars. Local colleges and universities also manage skill centers at AAM's major industrial campuses. The centers provide computer access, tutorials, and other reference materials for continuing education. Online training has proven to be a flexible and cost-effective mode of training that is easy to deliver, facilitate, and track for multiple worldwide locations. (Dauch – SME, 2005)

Terra Community College used a 2002 grant from the Society of Manufacturing Engineers (SME) Education Foundation to provide more flexible learning options, such as distance learning, for its engineering students; offer new courses in communications, industrial computing, and graphical interfaces; and partner with companies, including General Mills, to present targeted courses. Since SME formed its Education Foundation in 1979, it has invested over $15.5 million in grants. Along with its youth and scholarship programs, the Foundation's grants support the advancement of manufacturing education, and manufacturing as a career choice. Grants encourage collaboration between industry and educational institutions while stimulating the use of new and emerging technologies in manufacturing curricula. One direction in which this grants can be used is for distance learning in manufacturing.

Details about the SME Manufacturing Education current grants and scholarship programs can be found at www.sme.org/foundation.

Conclusions

The direction in which teaching for higher education in general, and for manufacturing engineering in particular, is going is Distance Learning. It is inevitable, and understanding the needs of students/faculty, curriculum changes, the technology support available, and how to apply the correct teaching/learning methods are a must. The future will bring more and more online programs in manufacturing, including hands-on experience at a distance. This will enhance the experience and knowledge of the manufacturing engineering and prepare him/her for the complex, global environment of the 21st century.

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