Session IS 11

Development of Manufacturing Systems Curricula in the Greenfield Paradigm

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ABSTRACT

The objective of this paper is to describe some of the content and progress in the development of the manufacturing systems knowledge area as defined by the Coalition for New Manufacturing Education. The paper also provides brief background information on the Coalition, Focus: HOPE and the perceived need for change in manufacturing education. Specific educational modules being developed as part of the manufacturing systems knowledge area are also described.

BACKGROUND

The Coalition. The manufacturing systems knowledge area is being developed under a paradigm defined by the Coalition for New Manufacturing Education which includes six universities (University of Detroit Mercy, the lead university, Central State University, Wayne State University, Lawrence Technological University, University of Michigan, and Lehigh University), Focus: HOPE and several leading U.S. companies. As a key partner in the National Science Foundation-sponsored effort, Focus: HOPE provides an innovative educational facility in which the potential candidates for degrees receive extensive manufacturing training and education while also producing high-quality products.

Focus: HOPE’s Center for Advanced Technologies (CAT) is the greenfield platform for educational innovation in partnership with academia and industry. This 220,000-square-foot facility maintains state-of-the-art manufacturing equipment and fully integrated electronic information systems.

Students at the Center learn in a real manufacturing environment, supplying parts to companies such as Ford Motor Company and Detroit Diesel. Allowing for access to this operational factory setting for educational development is a critical element in the manufacturing systems knowledge area.

The Need for the Greenfield Approach to Manufacturing Systems. Working effectively in today’s manufacturing organizations requires an understanding of the company as a whole. With the trend toward more agile enterprises, engineers are assuming more of an entrepreneurial role in the corporate organization. It is becoming increasingly evident that we can improve the way we prepare our engineers for these new global challenges. It is no longer sufficient to simply master one’s own task without being familiar with other aspects of the operation. Engineers must be able to think across a wide variety of disciplines (lateral thinking). Therefore, it seems logical that engineers should be educated in such a holistic manner, where the traditionally individual curricular components are connected and integrated.

The Coalition For New Manufacturing Education is in the process of combining innovative instructional processes with the state-of-the-art resources available at Focus: HOPE’s CAT facility to create a new educational model. In this "greenfield" approach the Coalition is that taking a broad and lateral view of the development of a manufacturing education program. It is hoped that this will contribute to establishing a lifelong habit and method of inquiry. Through a modular approach to curriculum design, the Coalition has created a program where "threads" of knowledge cut across traditional course and department boundaries. Students in the program learn manufacturing
through relevant processes, not isolated functions. This allows them to better understand manufacturing as a system and how the many parts relate and interact.

THE MANUFACTURING SYSTEMS KNOWLEDGE AREA

Learning how to analyze and design manufacturing systems in the context of real-world examples will help potential manufacturing engineers gain an enterprise-wide view of the business world. Thus, this introductory knowledge area encompasses several key areas in the study of manufacturing systems. The development process utilizes direct linkages to the daily experiences and activities of the Focus: HOPE candidates on the factory floor. Mastering these curriculum components, or modules, will set in place a foundation for future study and "elective" courses in specific topic areas. The knowledge area emphasizes an understanding of individual elements of a manufacturing system, as well as stressing technical competency in techniques to analyze and design fully integrated systems.

A brief description of the modules included in the two-year pilot effort being developed by Lehigh, Central State and Wayne State universities are as follows:

Fundamentals of Manufacturing Systems Design. This essential introductory module of the first-year offering of the Manufacturing Systems Knowledge Area provides an overview of manufacturing systems design. Students learn about the various types of manufacturing systems, such as job shops, project shops, batch production, cellular systems, flow lines and continuous systems. This module also introduces the students to the methods and tools used for manufacturing systems analysis and design. Students are also introduced to common industry practices in manufacturing systems design.

Analysis Techniques. By learning about and practicing various techniques in a real-world setting, graduates will be able to dissect a manufacturing system into its elements and understand their interactions. In this module, students learn how to construct and make use of graphical representations of manufacturing systems. In addition, students learn how to mathematically model a manufacturing system using the Cincinnati Milicron engine component line or the Detroit Diesel pulley production activity at the Focus: HOPE facility as case studies. The curriculum also includes the use of computer simulation as a tool to help the student to learn how to analyze the operations of a manufacturing system. The above-described approach helps students in solving unstructured problems similar to those they will encounter in industry.

Communications and Networking. It is planned that this module will give students an introductory understanding of how networking and data communication technologies enable them to realize and implement operational strategies, such as those based on agility and concurrent engineering. With the advent of improved information system technologies, an understanding of networking and communication capabilities is becoming increasingly important to manufacturing operations. Students also learn how manufacturing activities are integrated with other business and engineering processes of the enterprise and how networking can facilitate these ties. Team projects, case studies and exercises utilize a virtual prototyping approach to the learning process. After this module they will be ready to take further coursework in areas such as database systems design.

Human Factors. The manufacturing systems curriculum stresses human factors as a vital issue to an organization's success. Graduates will be able to assess the effects of the working environment on employee efficiency, loyalty, productivity, creativity, and enthusiasm. In this module, human factors issues are tied to actual student experiences in the Center for Advanced Technology. Team projects tied to real-world, unstructured problem solving are being developed and tested. The case-study method will be the primary delivery vehicle.

New operational models. New operational models play an increasingly important role in competitiveness as we enter the next century. Therefore, it is important that engineering education presents at least several of these cutting-edge manufacturing concepts. The curriculum will give students an understanding of the current issues and developments in manufacturing technologies and theory, such as agile manufacturing, just-in-time (JIT), synchronized manufacturing, and total quality management (TQM). In each case, these will be mapped against the appropriateness of the model or technique for the specific case problem at hand. Graduates will be able to apply new operational models to the design or re-engineering of traditional
manufacturing systems. New developments as the result of research in the field will be continuously introduced in this module. Relevancy determination will include strong industry input to the review process. This module is a foundation for students who want to take additional courses in new operational models.

**Systems (Operations) Management.** An engineer's role in manufacturing is an integrated one. Therefore, the curriculum will introduce students to issues and techniques in operations management. With module elements linked into other components of the manufacturing model, graduates of the program should have a solid understanding of the dynamics behind creating a new product and operating the enterprise which produces it.

**Planning and Executing Change.** Finally, the manufacturing systems knowledge area will cover the development of effective strategies for planning and executing change. It is anticipated that graduates of this program will become agents of change. They will be sought by companies that want to remain successful by use of effective strategic planning and design when attempting to implement new technologies. Graduating engineers must understand how to harness new technologies in a way that will be of greatest benefit to their company and have the confidence and leadership qualities to carry out implementations. Students will learn to align these technologies with the basic business model. It is anticipated that student-run companies will eventually work in partnership with industry to design or re-engineer manufacturing systems operations.

**EDUCATIONAL APPROACHES**

**Modeling The Factory.** Educating engineers for the manufacturing arena should include an emphasis on real-world experience. Many believe that engineering students most successfully retain knowledge and understanding when they see and do things, in addition to listening to how things are done. The Center for Advanced Technologies at Focus: HOPE is an ideal platform for the inclusion of real-world hands-on experience. Therefore, the manufacturing systems course modules are using this Center as a key resource in its program design.

Students entering the Coalition’s program are primarily graduates from Focus: HOPE’s Machinist Training Institute (MTI). Unlike many students at higher-education institutions, most students entering the greenfield program have a solid foundation of hands-on factory experience and a solid understanding of the factory floor. The CAT manufacturing facility and production activities provide a common foundation that ties together the curricular modules. Rather than being assigned generic textbook problems to apply their knowledge, students learn in the context of a real manufacturing environment. Through real-time factory applications or Center-based case studies, students practice their skills and techniques in an environment that is both familiar and realistic.

In order to transfer this approach to other settings a part of the factory operations is being modeled and a factory simulation is currently being developed. To ensure the accuracy of the simulation, Lehigh University development engineers have worked on-site at the Focus: HOPE facility to gather information such as a detailed plant layout, including operational characteristics of pertinent work centers, and to obtain feedback from both Focus: HOPE personnel and the students themselves.

It is anticipated that the simulation will be used for presentation purposes and will be a useful educational tool. It will enable students not on-site to interact with simulated factory events. They will gain insights into how the factory actually operates and work through "what if" scenarios to learn how changes, such as different batch sizes within the factory affect the overall plant operations. In this work there is an emphasis on the value of computers as "partners" in manufacturing system design and analysis. Finally, it is also expected that the simulation will become an important tool in subsequent operations research courses.

**Integrated Curriculum Development.** In attempt to give students an enterprise-wide view of manufacturing, multiple knowledge areas are being incorporated into the overall structure of the manufacturing systems curriculum (e.g., through interactive engineering case studies). Clearly, there is no single knowledge area that can or should function in isolation and it is inherently problematic if our engineers are taught in such a manner. Moreover, it is felt that this approach will be highly motivational to the students and recognized as beneficial by the companies that hire them.
For example, in the manufacturing systems knowledge area course material is being linked across fields and disciplines that have traditionally operated in separate spheres. Development and implementation of the manufacturing systems and communications knowledge areas has been carried out concurrently to the benefit and enhancement of both knowledge areas. Initial anecdotal evidence indicates that an assignment as simple as a case study analysis comparing current factory operations to a more automated process becomes more valuable from an educational standpoint when the technical direction of an experienced manufacturing engineer is coupled with the guidance of faculty schooled in the methods of effective written and oral communication.

More specifically, in terms of the communications knowledge area, it is logical that technically oriented people derive more benefit and satisfaction in analyzing and reporting on the capabilities of a new piece of equipment than the more generic essay typically assigned in a communications course. Thus, when examining the structure of the manufacturing systems curriculum it is readily apparent that the interest of the students is more easily captured and maintained and retention is increased, as the classroom material is immediately relevant and meaningful to them.

MULTIMEDIA DEVELOPMENT

Learning partnerships. Cooperative development of the multimedia component of the manufacturing systems courseware is essential to its successful incorporation into the overall curriculum structure as a viable educational tool. In light of this fact, Lehigh and its other university partners are developing and incorporating computer-based techniques which help to capture user commentary and suggestions. Thus, industry reviewers and the Focus: HOPE students themselves provide frequent feedback in the development of the computer-based learning modules. It is believed that this will enhance the quality and usefulness of the final educational products.

LINKS TO HOME INSTITUTION

Fully cognizant of the benefits of a greenfield approach to education for their own students, the Coalition partners are working to incorporate the main tenets of the greenfield paradigm into the curriculum structure and operations of their own institutions. The following sections briefly are examples of some of the efforts in this direction by Lehigh University which likely parallel the activities of the other Coalition schools.

Integrating courses across disciplines. The Industrial and Manufacturing Systems Engineering Department at Lehigh University is one of the many departments within the University fostering a more integrated approach to curriculum structure and course delivery. For example, business college students enroll in the course, "Management of Operations in Organizations," which focuses on the design, operation and control of activities necessary to generate goods or services of profit and nonprofit organizations. These students attend classes in the Computer-Integrated Manufacturing Laboratory as part of their normal curriculum. This class utilizes coalitional-developed educational materials to reinforce topics covered in a segment of the course focusing on information technology in manufacturing, and the issues covered include manufacturing systems design, numerical control, robots and programmable machines and automated guided vehicles. Early evidence indicates that the combination of this more technical perspective with the traditional business presentation provides the students with a much clearer picture of the information than would either approach delivered alone.

New design of CIM Lab. In keeping with the concept of learning partnerships, a classroom area and development space within the Computer-Integrated Manufacturing Lab at Lehigh University has been redesigned to try out and implement newly developed course materials. In place of the traditional, and rather sterile self-contained cubicles typical of some office spaces today, the developers are now working in an agile, open environment in which desks and computer terminals are shared and traded frequently. Thus, individuals situate themselves in a location conducive to their current work assignment, physically placing themselves near others on their project team when beneficial. Moreover, the new layout of a section of the laboratory includes a interactive, multimedia distanced-learning classroom area which will be an essential component in home institution dissemination of the greenfield courseware and ultimately dissemination beyond the original Coalition members.
CONCLUSION

To date, the greenfield partnership approach has been working well for initial development purposes. For example, in most cases the traditional topic areas can be coupled to the Focus: HOPE factory setting to enrich the learning experiences. However, at this point in time these should be viewed as pilot endeavors and the assessment phases are being planned but have not been completed.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to Joe Petrosky and the Focus: HOPE candidates for their feedback and guidance throughout the development process. We would also like to acknowledge the role of the National Science Foundation in these endeavors, as the project would not be possible without NSF funding support.

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