

The Integration of Laboratory Based Computer-Aided-Methodologies into a Manufacturing Engineering Technology Curriculum

Radha Balamuralikrishna, Clifford R. Mirman, and Andrew Otieno
Northern Illinois University

Abstract

Northern Illinois University (NIU) is strategically located between the major metropolitan areas of Rockford and Chicago, Illinois. This region encompasses many different types of industries, and thus, the departmental graduates must have a very diverse educational background. To address the needs of industry, NIU's Manufacturing Engineering Technology (MET) program has recently revised its curriculum and embarked on several laboratory enhancement projects. In redesigning the curriculum, the department emphasized integration of subject matter and computer skills across courses. It is this strategy that we wish to exploit in order to achieve a unique status among similar programs across the region and the nation. To reflect industry needs, the department has redesigned courses in numerical control, programmable logic controllers, and computer integrated manufacturing. The department is also in the process of developing an automation course and related laboratory experience that will integrate several areas within this complex field. In the automation course, the students will look at integration of motion, vision, sensors, and robotics. In addition, MET majors will be required to enhance their skills in manufacturing analysis, thus enabling them to become more active partners in the ever increasing domain of Integrated Product and Process development (IPPD).

Introduction

As Manufacturing Engineering Technology (MET) educators, we must periodically reexamine the skills required by our graduates to meet the multi-faceted challenges in their future workplaces. The need for continuous reengineering of the curriculum is driven by industry's penchant to reduce costs and increase productivity in a globally competitive economy. In an era of explosion of knowledge and information, educators must make wise choices in deciding what should be taught within the scope of a typical four-year degree program. Recognizing that new ideas and innovations constantly emerge in manufacturing, employers ideally seek graduates who possess considerable command over a wide range of subjects and skills. Graduates who demonstrate that they are proactive learners and have reasonably mastered "how to learn" are usually placed on a priority list during the hiring process. At Northern Illinois University, the Technology Department is reexamining avenues to increase subject matter and computer skills integration across a broad spectrum of courses that are offered to MET majors. These changes have occurred with assistance from both the departmental industrial advisory board, and from selected companies in the areas of concern.

The main thrust of the new curricular reform has been in the area of integration of content and computer skills across courses. Prior to this restructuring, the departmental course offerings were lacking in these aspects. The older program provided more flexibility in terms of number of

different courses a student may choose from in order to acquire the 127 credit hours required for graduation. The limitation here was that a student could earn in degree in MET and still not have attained competencies deemed vital to a MET graduate entering the global workforce. Several authentic studies have delineated the competencies of emerging 21st century MET graduates; the report published by the Society of Manufacturing Engineers deserves special mention¹.

The broad objectives in designing a new curriculum were:

- It should prepare graduates who can easily make the school to work transition;
- Students should have the core requirements in old technology areas, i.e. machining, welding, metrology, and etc.
- Students must have knowledge in "new" areas in manufacturing, i.e. automation, programmable logic controllers, numerical control, and metrology.
- Students must have computing skills as well as presentation abilities.
- The changes must also pave the way for ABET accreditation (TAC) of NIU's MET program.

Regional Impetus

In the state of Illinois, the projections for skilled employees in manufacturing have continued to grow significantly over the past decade. According to the Illinois Occupational Information Coordinating Committee (IOICC), the state will require nearly 7 million new workers by the year 2008. The study further suggested that on an annual basis, over 80,000 new job openings would arise and need to be filled. Projected job growth by occupational group revealed that professional, technical and service sectors would add the most new jobs through 2008. The majority of these will go into manufacturing². To meet manufacturing demands in particular, institutions at all levels must respond by preparing highly qualified and competitive professionals. NIU has recently been admitted to NASULGC (National Association of State Universities and Land Grant Colleges), and with this status an increased volume of regional outreach has been earmarked as the next logical step in the growth of the university.

The Department of Technology at NIU is preparing to meet the regional manufacturing related challenge by redesigning the MET curricula and improving laboratories. The department is already seeing increases in student enrollment, and by stressing "quality" of educational experiences, we hope to attract even more potential students. Some of the major companies that actively recruit our graduates include Ingersoll Cutting tools (Rockford), RR Floody Company (Rockford), Motorola (Rockford, Aurora), Sunstrand Corp. (Rockford), Chrysler (Rockford), Siemens (Chicago), Nissan Forklift (Marengo), Caterpillar (Aurora, Peoria) and Underwriters Laboratories (Northbrook), just to name a few. These companies also participate actively in internships, co-operative education, senior design projects and continue to remain an excellent resource for maintaining an Industrial Advisory Board.

Major Revisions in the Program of Study - Perspectives and Action

Where as historically important parameters such as productivity and quality continue to remain important for competitiveness in the manufacturing enterprise, flexibility and agility are the emerging watchwords. In many manufacturing sectors, trends are rapidly changing to flexible automation. According to Jeffrey Kao, vice president of CNC and Laser Businesses, GE Fanuc Automation, faster processors, more sophisticated control design and automated systems have

facilitated these developments in manufacturing automation³. A sound curriculum in manufacturing automation must include but is not limited to robotics, motion control systems, programmable logic controllers, computer numerical control machines, materials handling systems, manufacturing vision systems, computer-aided testing, automated materials handling systems and automated storage and retrieval systems. As observed by the SME, "...Students with a solid grounding in science and math, strong hands-on project experience and teamwork skills make the best manufacturing engineers"⁴.

Although several changes were made to the program keeping our objectives in mind, we will focus here on the major issues. In general, the program changes initiated have allowed the department to integrate either new skills or advanced skills into our curriculum. Table 1 shows the redesigned MET program for the 2001/2002 academic year. As a result of this redesign, the following changes have been incorporated into the NIU MET program:

- Computer-Aided-Design - All MET majors were required to take a first course in technical drawing which employed manual drafting techniques. The usage of the drawing board has been replaced and the course was eliminated as a requirement; however the subject matter was covered in a different course (TECH 211) that exclusively employed computer-aided design (CAD) techniques and taught the students drafting principles using the computer as the medium.
- Programming - In the past, MET students were required to take two computer based courses; one which taught the basics of C programming and the other instructed in the basics of using Microsoft EXCEL. Based upon input from the departmental advisory board, the department has switched from C to Visual Basic (Tech 395). In addition, we have dropped the EXCEL course and are instructing the students on this important software usage in a variety of other courses. The incorporation of Visual Basic is very important, as it will be the basic programming tool for several other courses in the curriculum.
- Engineering Economy - This important course (Tech 443) was added as a requirement to the program. Introducing engineering economy as a core requirement challenged students to enhance their business skills, a serious deficiency among MET graduates across the nation (Manufacturing education plan, 1997) Further, spreadsheet tools are also be applied in the context of problems that address engineering economy.
- Design Techniques - Again, based upon input from our departmental advisory board, the department felt that the students needed to see more design concepts within the manufacturing environment. To integrate these design concepts into the program, the Manufacturing Component Design course (TECH 342) was initiated. This course integrates two topics together, namely, solid modeling and planar mechanisms; two areas which would significantly challenge and better prepare students in integrating design with manufacturing. In this course, the students will be introduced to SolidWorks and concepts like gears linkages, and cams.
- Automation Techniques - The department has made a concerted effort over the past two years to broaden the students knowledge into "new" areas within the manufacturing realm, or

automated manufacturing, by altering an existing course and adding one new course. The Computer-Integrated-Manufacturing course (Tech 420) has been altered to give a broader view of the use of computers in manufacturing, and includes numerous opportunities for hands-on learning. In addition, a lab/lecture Automation course (Tech 423), which will teach the basic and advanced subjects of sensors, robotics, pneumatic control, and vision, has been added.

In the integration of laboratory based computer methodologies into the curriculum, the department examined the best modes for integration. In striving for integration, and proper covering of the needed material, the department looked at how material was covered, and the proper overlap of instruction. To this extent, we also had to separate the areas into "new" and "old" technologies. In terms of the older technologies, like welding, metal forming and working, the department has laboratories in place. It was in the "new" areas, like computer-integration, automation, PLC's, numerical control, and metrology, that the department needed to develop laboratory experiences.

There is always a need in manufacturing to reduce the cycle time from concept to production. Integrated product and process development (IPPD), sometimes also called simultaneous engineering) is the answer for slashing lead times for new product development. The IPPD environment forces a product development team to undertake engineering analysis during early stages even during concept design. Future MET graduates should be comfortable in interpreting and applying finite element analysis (FEA), a very popular and powerful tool for engineering analysis. MET majors at most institutions have opportunities to acquire good solid modeling skills and FEA has grown and matured as a versatile downstream application of solid modeling. A new course titled Manufacturing Analysis (TECH 497- currently) was introduced into the curriculum. A comprehensive study of finite element analysis (assisted by the ANSYS software package) is covered in this course using a practice-based approach in which students spend more time on applications as opposed to learning theory. Students are required to apply prior knowledge from calculus, statics and strength of materials in this new course.

NIU's Technology Department is not only integrating these computer-aided engineering (CAE) concepts at the individual course level, but also structuring our yearlong capstone experience to integrate these CAE topics into industry sponsored projects. At this point, we are working with local companies to structure group projects in which several areas within the realm of CAD/CAM/CAE are commingled such that the student teams must solve problems that offer a wide array of challenges addressing both design and manufacturing. Such demanding problems will require that students integrate knowledge and skills from a broad spectrum of courses in order to recommend feasible solutions.

Enterprises must also now focus not only on faster throughputs but distributed information management through computer integration. Future engineers will therefore need to participate aggressively in the "value adding" process of manufacturing, increase product quality, reduce costs and contribute to the whole productivity of the enterprise⁵. Clearly, it is important that manufacturing engineers need to be trained in the different stages of product development and how these integrate with manufacturing and automation⁶. However most courses in manufacturing tend to be limited to just CAD/CAM integration. Students rarely get a chance to

gain the necessary experience of the entire process of product realization. It is envisaged that our department's new line of thinking for our MET program will help narrow the gap between design and manufacturing entities. Participation in enterprise productivity will also require that the new manufacturing engineer be well versed with current trends in manufacturing and automation, and have a sound hands-on training in the relevant areas of automation.

Laboratory Upgrades and Industry Support

Well-equipped laboratories should support engineering technology programs. According to ABET guidelines, MET programs should have in-depth coverage of the relevant area, should be broad and should also include as much laboratory and practical experience as possible⁷. Acquiring and maintaining modern manufacturing laboratories can be challenging because equipment is expensive and the budget at most academic institutions remains relatively small compared to needs. Our department is not an exception to this general situation and hence creative efforts are constantly required to acquire most equipment additions. We realized that area industries could help us with some of our needs if only they knew more about our program. Therefore, communicating the potential strengths and needs of our program emerged as an important agenda item and these efforts have resulted in success.

After developing the proper curriculum and course links, the department turned its attention to the laboratory sequence and equipment. In several cases like the CNC and PLC course, new equipment and/or software was purchased. However, in the other areas, new labs had to be developed. In the metrology area, we worked with a supplier and developed a new experience based on existing measuring devices, and new computer-controlled devices. It was in the automation area that a completely new lab experience was undertaken. Space for the new automation laboratory was allocated and then refurbished. The automation area has a modular flexible-manufacturing cell that consists of two specific working areas. The first is an automated machining center devoted to activities involving machining operations, consisting of a CNC milling center and a CNC lathe; two robots are used to load the machining centers. The parts are loaded manually on to conveyor system. Transfer between the milling conveyor and the turning conveyor is through pneumatic pick and place devices. The second automation area will involve automated assembly processes. This area utilizes an existing conveyor loop and eight stations for assembly operations. One robot is used for loading the conveyor loop. Pneumatic pick-and-place units perform load-unload operations at each station. Vision systems and bar-code readers complement part identification and inspection. Each station employs programmable logic controllers for control of machine motions and actions.

Technologies such as rapid prototyping are widely being used in industry to reduce the product design cycle time. Beginning Fall 2000, students enjoyed having access to a Z-Corporation's Z402™ rapid prototyping machine. This machine uses cornstarch as the base material (non-hazardous and easy to handle), and is relatively inexpensive to operate. This machine was obtained from Z-Corporation at a significantly discounted price that was made possible through a company grant. Efforts are underway to employ this machine for producing concept models for area industries and further generate money for laboratory maintenance and upgrades. The ability to design parts using parametric solid modeling and then quickly being able to create and examine a prototype of one's design is an exciting experience for students.

Students are currently transferring their solid model database to CAM software, such as MasterCAM and SurfCAM to generate CNC codes. Several manufacturing engineering technology programs do provide their majors excellent opportunities to learn CAD/CAM integration. However, very few programs address computer-aided process planning (CAPP), a major link between CAD and CAM. Plans for the future will focus on executing even more downstream applications of solid modeling and how the usage of solid modeling technology can be maximized for effective implementation of simultaneous engineering including process planning and the exchange of information in global manufacturing. Our goal is to maximize student learning and direct more and more experiences that are linked to the real world application of IPPD.

Concluding Remarks

During the past year, the department of Technology at Northern Illinois University has made a concerted effort to upgrade its undergraduate manufacturing engineering technology degree program. Recognizing that more and more entry-level graduates are being asked to use an integrative approach to resolve manufacturing issues, the department has effected curricular changes and laboratory improvements. We have established a more structured sequence of coursework for the students, and identified better ways to integrate knowledge and computer skills across courses, particularly those being offered at the junior and senior levels. Of significance is the improvement of courses in automation, introduction of additional coursework in engineering design including finite element analysis.

The department continues to expand its relationship with the surrounding industrial community and would like to further enhance these ties to develop an outstanding MET curriculum. This partnership is extremely important as manufacturing needs change quickly over time and the department would like to remain agile in terms of preparing graduates ready to meet contemporary challenges. These collaborative efforts with industry have also helped us in establishing a new automation laboratory and adding significant new equipment to our existing facilities. We feel that our current emphasis to integrate the knowledge and skills across courses will result in preparing graduates who have a wider and more in-depth exposure to the world of manufacturing.

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RADHA BALAMURALIKRISHNA

Radha Balamuralikrishna (Bala) received his Ph.D. degree from Iowa State University in 1997. As a Naval Architect, he completed several projects in structural design of ships and offshore structures during the late 1980s. He is currently an Assistant Professor in the Department of Technology at Northern Illinois University teaching courses primarily in the CAD area. Dr. Bala is actively involved in professional societies including the American Society of Engineering Education (ASEE), and the Society of Manufacturing Engineers (SME)

CLIFFORD R.MIRMAN

Clifford R. Mirman received his Ph.D. degree from the University of Illinois at Chicago in 1991. From 1991 until 1999, he was a member of the Wilkes University Mechanical Engineering Department. He is currently the Chair of the Department of Technology at Northern Illinois University. During his tenure at Wilkes University, he was active in the areas of CAD, Finite-Element-Analysis, and kinematics, both securing grants and writing publications. Dr. Mirman is actively involved in the American Society of Engineering Education (ASEE) and Society of Manufacturing Engineers (SME).

ANDREW OTIENO

Dr. Andrew Otieno received his Ph. D degree from the University of Leeds, U.K. He joined Northern Illinois University in Fall 2000 and teaches courses in basic manufacturing, automation, and computer-aided manufacturing. He has worked as a post-doctoral researcher in the Mechanical Engineering department at the University of Missouri-Rolla before assuming his current role as Assistant Professor.

Manufacturing Engineering Technology BS/MS Course sequence	
Catalog - 2001/2002	
Total undergraduate credits	127
Freshman (fall)	Freshman (Spring)
3 Tech 211 - CAD	4 Math229 - Calc I
3 Math155 - Trig	3 Eng104
4 Chem 110a (or Chem 210)	3 Stat 208 (or Stat301)
3 Eng103	3 Gen Ed
3 Gen Ed	3 Gen Ed
16	16
Sophomore (fall)	Sophomore (Spring)
4 Math 230 - Calc II	3 Tech 360 - Machine Production Process
3 Gen Ed	3 Gen Ed
4 Phy 250	4 Tech 310 - Statics & Dynamics
3 Tech 265 - Manufact. Processes	3 Coms 100 - Basic Communications
3 Tech175 - Electronics Fund.	3 Tech 395 - Visual Basic Programming
1 Tech175a - Electronics Lab	16
18	
Junior (fall)	Junior (Spring)
3 Tech 426 - Fluid Mechanics/Lab	3 Manufacturing Process Elective 2
3 Manufacturing System Elective 1	3 Tech 393 - Properties of Matl's
3 Tech 369 - Strength of Matl's	3 Tech 420 - Computer-Integrated-Manufacturing
3 Tech 425 - PLC	3 Manufacturing Process Elective 3
3 Manufacturing Process Elective 1	3 Tech 342 - Manufacturing Component Design
15	15
Senior (fall)	Senior (Spring)
1 Tech 477 - Senior Projects I	3 Tech 478 - Senior Project II
3 Gen Ed	3 Gen Ed
3 Tech 423 - Automation	3 Tech 362 - Numerical Control Systems
3 Tech 443 - Engineering Economy	3 Manufacturing System Elective 3
3 Tech 491 - Industrial Quality Control	3 Manufacturing Process Elective 4
3 Manufacturing System Elective 2	15
16	
Manufacturing Systems Electives (3 courses)	Manufacturing Process Electives (4 courses)
Tech 334 - Hazard Control	Tech 260 - Metal Fabrication Processes
Tech 394 - Industrial Project Management	Tech 312 - Design Dimensioning & Tolerancing
Tech 401 - Ethics	Tech 314 - Tool and Die Design
Tech 402 - Industrial Training	Tech 344 - Materials & Processes in the Plastics Ind.
Tech 404 - Industrial Supervision	Tech 345 - Plastic Molding Processes
Tech 408 - Conf. & Meeting Management	Tech 365 - Metrology
Tech 409 - Internship	Tech 479 - Special Topics in Engineering Technology
Tech 429 - Plant loc, Layout, and Mat Handling	
Tech 434 - Human Fact. in Accident Prev.	
Tech 442 - Work Simplification	
Tech 444 - Production Systems	
Tech 482 - Industrial Safety Analysis	

Table 1 - Northern Illinois University's Manufacturing Engineering Technology Program

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