AC 2009-1352: CURRICULA 2015: MOVING MANUFACTURING CURRICULA FORWARD

Hugh Jack, Grand Valley State University

Venkitaswamy Raju, State University of New York, Farmingdale

David Wells, North Dakota State University

Robert Mott, University of Dayton

Curricula 2015 – Moving Manufacturing Curricula Forward

Hugh Jack, Professor, Grand Valley State University
Venkitaswamy Raju, Professor, Farmingdale State College - SUNY
David Wells, Professor, North Dakota State University
Robert Mott, Professor Emeritus, University of Dayton

Abstract

This paper describes the process and results to date being undertaken by the Society of Manufacturing Engineers through its Manufacturing Education & Research Community (SME-MER) to move the curricula for manufacturing education forward. The goal is to ensure that graduates are well prepared to serve the wide spectrum of industry needs in a high-technology, globally competitive, and rapidly evolving world. The process builds on landmark work completed in the 1990s from which a series of publications emerged that defined content, program organization, and differentiation among associate degree, baccalaureate degree, and graduate degree programs. A variety of methods are being implemented to perform the updating of recommended curricula and the intended product has been called *Curricula 2015*, extending from the prior work. Most notable are a series of <u>Manufacturing Education Leadership Forums</u> held during 2008 and 2009 attended by professionals in academia, industry, and government. The NSF-sponsored *National Center for Manufacturing Education (NCME)* is participating in this effort and its Manufacturing Education Resource Center (MERC) provides support for the process along with means of chronicling and archiving the results. It is expected that a nearly final draft of *Curricula 2015* will have been completed by the time of the 2009 ASEE Annual Conference. Reporting on it will be timely and will give ASEE Manufacturing Division members opportunity to comment and provide input. Additional development will then take place immediately following the ASEE Conference in Austin, TX. Publication of the document is envisioned for Fall 2009. Collaboration among members of the ASEE Manufacturing Division, SME-MER, and other professional societies having interest in manufacturing education is essential to the success of this work.

The State of Manufacturing Education

Manufacturing Education programs have seen great change, arguably more than every other engineering discipline. These changes come in the form of number of programs, student enrollment, change in industrial needs, demands to update the curriculum, and an evolving definition of the discipline.

The number of accredited programs saw growth up to the end of the 1990s, with a decline thereafter. The decreases are the result of a tarnished image resulting from negative press about the manufacturing sector. Up to that point the focus had been on increasing the number of named manufacturing education programs and the economy was a nurturing environment for that growth. However after the downturn in the economy and the increase in outsourcing/off-shoring the trend in program creation and enrollment reversed.

Over time the manufacturing discipline has been changing to address industrial needs. In the past there was a heavy emphasis on manufacturing processes. This focus was formally expanded in strategic meetings in 1989 [1] and 1994 [2] to include topics such as business, planning, controls, and quality. The Curricula 2000 and Curriculum 2002 documents also defined sample curriculum and delineated differences between engineering and technology programs.

Since the Curriculum documents were published there have been a number of new developments including;

- A recognized increase in the role of business knowledge
- New methods such as Lean manufacturing
- Globalization
- Computer software and control methods
- New manufacturing processes
- New manufacturing sectors

To this end the work in the previous curriculum documents was revisited and used as the foundation for a new document, Curriculum 2015 [3]. The current structure of this document is shown below.

> Part I - Surveying the landscape:
>> What Industry Needs From Our Graduates
>> Predicting the future through research
>> Innovation in education
>> K-12 recruiting and outreach
> Part II - Surveying the educational process:
>> 2 year program issues and recommendations
>> 4 year program issues and recommendations
>> Graduate program issues and recommendations
> Part III - Goals and Strategies:
>> The role of education in preparing for our future in manufacturing
>> A plan to revitalize manufacturing education

What follows is a brief description of the state of each of these areas. These should be viewed as a work in progress that should be nearing completion in June of 2009.

What Industry Needs From Our Graduates

The discipline of manufacturing engineering is inherently tied to the current and emerging needs of the manufacturing industry. The diversity of manufacturers guarantees a large and diverse list of topics. It is widely agreed that while some of these are common to all industries, others are highly specific to manufacturing sectors and regions. A partial list of topics that have been generally identified as core requirements are itemized below.

- Project Management
- Global Perspective
- Methods such as six sigma, lean, layout design, and quality project management.
- Awareness of emerging trends - 'green', energy, sustainability, etc.

Industry typically asks for skills that are much harder to capture in a curriculum, but are essential to an effective engineer. These skills include,

- Common Sense and understanding of the fundamentals including money
- Creativity and problem solving skills, curiosity
- Able to deal with rapid change and new developments, work in environments of risk
- Craftsmanship, well trained, get it right the first time, always learning and improving
- Effectiveness - carry large tasks from beginning to end
- Social skills, communication, leadership, teamwork
- Ready for new knowledge
- Practical, big picture thinkers
- Work outside their defined roles, take leadership positions
- Look beyond their own role in the process, beyond the suppliers and customers

An exhaustive list of topics currently needed is easily obtained by looking at the publications catalog of a society like the Society of Manufacturing Engineers (SME). But looking forward the needs seem to be focused on emerging areas.

- New disciplines: Nano-materials and machines, bio-products, electronics
- Computer driven systems and processes
- New technologies driven by energy, environment
- Going beyond metals for materials and processes

Within the SME the Technical Community groups can act as a source of information for current and near industrial needs. These groups current include, Automated Manufacturing and Assembly, Forming and Fabrication, Industrial Lasers, Machining and Material Removal, Plastics Composites and Coatings, Product and Process Design and Management, and Rapid Technologies and Additive Manufacturing. These groups have many analogs in other societies.

Predicting the Future Through Research

The mathematics is quite simple for innovation in the curriculum. If we plan to make a change or addition to the undergraduate curriculum it can easily take three or more years if it requires major curriculum redesign and/or major expenditures on laboratory equipment. After this a student would need to take the course and could still be up to two years away from his or her first position. In simple terms we often need to look four or more years into the future to predict what will be cutting edge as our students enter the workforce. This problem has long guaranteed that there is a lag between industry need and graduate knowledge. Although some future developments are easily foreseen, many are not. To identify developments that can impact production within five to ten years we look to private and public researchers. Through their work they develop new solutions to old problems, and to develop innovations that redefine what we can do, and what the consumer demands.

Within the academic community the relationship between graduate studies/research and the undergraduate curriculum is understood, although not always formalized. The system is built upon faculty who do and/or direct research that they can then bring back to the undergraduate classroom as it bears fruit. Needless to say this approach is somewhat inconsistent based upon localized faculty expertise. Methods and approaches are required to formalize the ties between fundamental curriculum and research to increase the focus and impact of new developments.

This problem is remarkably difficult to formalize because of the ad-hoc nature of research. Luckily there are a few vehicles that can be used to identify educational opportunities and help bring them to the classroom. Within the SME there is the North American Manufacturing Research Institute (NAMRI) that holds annual research events. Over time increasing the educational ties to this group should help identify prime areas for education that can be introduced to the undergraduate curriculum ahead of industry demand.

Places where research topics are expected to have a direct input include,

- Senior level capstone courses and undergraduate course projects
- Upper level electives and advanced topics courses
- Exposure through co-ops and internships

Innovation in Education

Education is a process, much like any process in manufacturing. Universities bring in students and apply various techniques to transfer knowledge, skills, and abilities. The product is the graduates. However, unlike most production facilities education faces a variety of issues. These include a large variability of incoming students/faculty/knowledge/support, poorly defined product requirements (many unmeasurable), non-exact processes, and more. In more direct terms education is a very inexact process, and is likely to always be so. However this does not prevent aspirations to be more effective. To this end great effort is exerted (including this group) to provide the tools to make the outcomes of the process more effective.

Defining to outcomes of graduates is a constant struggle between many objectives. The ideal graduate would be very knowledgeable and capable in their chosen profession. If it were possible to expand the programs and hand pick the students this might be highly Utopian, but it is not a luxury that is afforded in the current educational environment. In practice a curriculum is a very pragmatic trade-off between time (typically 2-4 years), topics, and skills. Like any limited process for everything that is added something is lost. And, regardless of the compromise selected, there are always shortcomings.

Educators have been exploring a number of methods that make it possible to increase the impact of the curriculum. these are typically in one of a few categories; content delivery, experiential, and skill based. Some of the current and developing techniques are listed below.

* use the web and alternate methods to teach
* more dirty hands backed up by more theory and rigor
* teach student to work in unstructured environments
* modeling followed by implementation and validation

* resolving theory and practice

* appealing to different learning styles

* industrial outreach and making things relevant, real-world, career focused

* engaging-motivating

* appeal to the current social approach - highly connected and ad-hoc

* don't lecture, but work with them to solve problems

* competitions, open-ended design, projects, experiential learning

Some of the major issues with current educational practices are the variety of students in the process. These include the traditional undergraduate and graduate students, but these have joined by expanding numbers of professionals, part-time students, distant students, older/non-traditional students, and others.

There has been an appeal to universities to allow education to occur without the campus experience. There is active debate as to the feasibility of this approach given the hands-on nature of engineering education. However, this does not stop a number of innovators from trying to deliver manufacturing education remotely.

Despite a number of anecdotes, student motivations are surprisingly similar to those of decades past. Students still want to pursue an area that is intellectually stimulating where they can make a contribution. Very much like most engineering educators. What does differ is the preparation and expectations. The modern student is much more accustomed to a black box environment with very fast transactions. This is sometimes out of step with an educational format that was fine tuned centuries ago. Modern students are much more comfortable working in a task switching and information rich environment where information is accessed in a non-linear way.

K-12 recruiting and Outreach

Despite calls for revision of manufacturing programs - the largest threat to manufacturing programs is the very small number of incoming students. Most of the named undergraduate manufacturing programs in the country are declining in size because the number of incoming

students continues to decline. This is in the face of overwhelming demand for manufacturing engineers/technicians/technologists (even in the current poor economy). This decline is largely the result of a poor public perception that manufacturing jobs are leaving the country, never to return. In some ways this has truth for low skilled jobs, but it ignores the persistence and growth of highly skilled positions.

Groups such as the SME Education Foundation have turned their attention to increasing the number of students considering manufacturing engineering and careers. These efforts themselves are monumental and are being approached elsewhere. But, any efforts to build manufacturing education must address the K-12 constituency and other avenues that grow manufacturing professionals. Some of the identified groups are listed below.

- Underrepresented groups including women, economically/socially disadvantaged, and minorities.
- Students in other 'non-manufacturing' disciplines (e.g. MBA, science, etc.).
- Students in other related disciplines (e.g. Electrical Engineering).

Revising the 2 and 4 Year Curriculum

There have been many attempts to revise the curriculum of 2 and 4 year programs, and this should not stop in the future. The programs range from deeply-narrowly focused and hands-on at the associates level, to the broadly focused more abstract engineering level, with technology programs occupying a compromising role. The variety of topics is large and will comprise a large portion of the final report. Regardless of the recommendations these are to be used as templates and guides, not as prescriptions. They are to serve as a set of reference guides, or best practices that programs may draw from to design something suitable for their students and stakeholders. The list below shows a number of the current categories to be used in the final document.

Technological Competencies
- Product Realization Process
- Engineering Materials

- Engineering Mechanics and Design

- Manufacturing Processes

- Manufacturing Systems Design, Analysis, and Control

- Control of Machines

- Quality Systems

- Computer Systems

- Electrical Circuits and Electronics

Professional Competencies

- Communication

- Global Multiculturalism

- Teamwork

- Ethics

- Creativity and Innovation

Enterprise Management

- Project Management

- Manufacturing Information Systems

- Product Life Cycle Management

- Enterprise Resource Management

- Financial Management

- Human Resource Management and Supervision

- Entrepreneurship

- Intellectual Property Rights

Mathematics and Science Competencies

- Mathematics

- Physics

- Chemistry

- Bioscience

Graduate Program Issues

Given the small number of ABET (EAC) accredited engineering programs (less than 25 in 2007) there are few universities that have a dedicated department of Manufacturing Engineering. As a result manufacturing is often hosted as a sub-specialty in other engineering disciplines. This is also mirrored in the professional societies such as the ASME and IEEE that have substantial manufacturing divisions.

There are two primary divisions of graduate programs, course based and thesis/project based. Thesis based program are particularly difficult to identify because they are largely driven by the research interests of the chief advisor and are often in programs other than Manufacturing engineering. Course based programs are often tied to accredited undergraduate manufacturing engineering programs, with the exception of the University of St. Thomas with a Masters level accreditation.

* Project/Thesis Based
* Course Based
* Part/Full Time

Many students in manufacturing grad programs often do not have manufacturing undergraduate degrees. For these students the graduate level coursework is often directed towards learning a variety of manufacturing fundamentals. The students are often motivated by work post-graduation work experiences where they found themselves required to do manufacturing engineering. In many cases these students are partially or completely funded to do their graduate work.

* full-time
* part-time
* international/domestic ratio
* students more mature
* Financial support

A Plan to Revitalize Manufacturing Education

The final report will not only include suggestions for improving the curriculum, but it will also include a strategy for making manufacturing education stronger. To this end it will include the following elements.

Appealing to Students
    empowered, free individuals
        * flexible time, not punching clocks
        * not tied to a desk or a production line
        * managing large budgets and many people
        * more dynamic career choices
        * important roles in companies including management
    active
        * designing and building
        * using new high-technologies, computers and methods
    people oriented
        * work with a diverse group of people in multiple disciplines
        * travel to many interesting places and cultures
    rewarding
        * helping society and making a difference
        * good salaries, benefits and bonuses
        * determining the best ways to satisfy customers

Defining The Discipline
    Recognize Products as the driving force behind our discipline, and change the program name.
    Promote the positive image of the discipline to the general public (industry, students, parents).
    Attract academically strong, high achieving students.
    Revise the curriculum to address the new needs of globalization.
    Clarify the definition of Manufacturing Engineering.

Encourage a recognition of the differences between Manufacturing and other disciplines.

Differentiate between 'Product Design' and others such as 'Mechanical Design".

What next

It is hard to modify and grow manufacturing programs when the economy is so weak and many school would prefer to close their programs. But a strong plan that helps shape vision and unity will make it possible for supporters and educators alike to work towards a healthy future for the next generation of manufacturing.

Bibliography

1. Arther, A. A., Wells, D., Demers, P.J. (editors), "Ideal Models in Manufacturing Education; Curricula 2000 Workshop Proceedings", Society of Manufacturing Engineers, 1990. (http://www.sme.org/cgi-bin/get-event.pl?--001779-000007-home--SME-)

2. Wells, D. (editor), "Manufacturing Education for the 21st Century – Volume I: Curricula 2002 Report", SME, 1995. (http://www.sme.org/cgi-bin/get-event.pl?--001779-000007-home--SME-)

3. "Curriculum 2015", Society of Manufacturing Engineers, (to be completed) 2009.

   (http://www.merconline.net/wiki/index.php?title=Curriculum_2015)

4. Jack, H. (editor), "Manufacturing Education Leadership Forum: Vision for Progress", Society of Manufacturing Engineers, 2008. (http://claymore.engineer.gvsu.edu/~jackh/sme/pittsburgh08/Program.html)

5. Jack, H. (editor), "Manufacturing Education Leadership Forum; Moving Forward", Society of Manufacturing Engineers, 2008. (http://www.merconline.net/wiki/index.php?title=Farmingdale_Forum_Program)

6. Jack, H. (editor), "Manufacturing Education Transformation Summit 2009", Society of Manufacturing Engineers, 2009.

7. "Manufacturing Education & Research Community Wiki" (http://www.merconline.net/wiki)