An Interdisciplinary Undergraduate Manufacturing Engineering Option for Chemical Engineering

by

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Abstract

In 1994, ARPA/TRP (through NSF) granted a trio of engineering schools - Penn State University, University of Washington and the University of Puerto Rico at Mayagüez (UPRM), in partnership with Sandia National Laboratories - a two year project to develop and institutionalize an undergraduate manufacturing engineering option for the three institutions. The project aimed at addressing industry and business needs for a new breed of skilled professional, by developing an option with a new and fresh approach to engineering education: a hands-on, practice-based option, emphasizing skill development and using non-traditional teaching techniques. The project called to develop this option for the Departments of Industrial, Mechanical and Electrical Engineering. Three major courses have been created and are currently being pilot tested at the three institutions: Product Dissection, Concurrent Engineering, and Entrepreneurship. The sequence of courses culminate with a re-engineered capstone design course wherein students solve/design a real-life problem. At UPRM, this option is also being developed for the Chemical Engineering program, thanks to a grant recently approved by the Procter & Gamble Educational Fund (one in four grants they bestowed nationwide). This paper describes the principal activities being carried out in the first year of the project, an effort that complements and capitalizes on the NSF-TRP project. It will describe the option (which consists of a list required and elective courses from various engineering departments and the Business School), the new courses being created or re-engineered (Chemical Manufacturing Processes, Plastics Engineering, Capstone Design based on industrial problems), and its major highlights, including learning activities, assessment methods, laboratory enhancement to provide for hands on activities, and collaboration with industry. Courses are expected to be pilot-tested during academic year 96-97 and the manufacturing option will be fully implemented by academic year 97-98. Outreach of pertinent course material and dissemination of the manufacturing option is also contemplated.

Background

The need for a skilled professional engineer has been identified by both engineering educators and the employers of recent graduates. In 1992, for example, the National Society of Professional Engineers published the results of a national survey of opinions on the professional engineering degree[1]. Not only is a sound scientific and technological base knowledge required in a recent graduate, but the surveys identified specific skills that are highly valued by those who hire engineers. **Communication skills, teamwork, leadership and integrative thinking** were recognized as among those that would merit more attention in a revised engineering curriculum. Unfortunately, traditional engineering programs and engineering education, in general, have not been dynamic enough in addressing these issues. Engineering schools across the nation provide students with few practical experiences and applications competencies, as desired by business and industries seeking to employ these graduates.

In response to this need, in 1994 ARPA/TRP (through NSF) granted a trio of engineering schools - Penn State University, University of Washington and the University of Puerto Rico at Mayagüez (UPRM), in partnership with Sandia National Laboratories - a two year project to develop and institutionalize an undergraduate manufacturing engineering option to be shared among the three institutions. Thus, the **Manufacturing Engineering Education Partnership (MEEP)** came to be.

MEEP Goals and Deliverables[2]

MEEP aims at demonstrating a new paradigm for the undergraduate engineering experience by providing proper balance between science and engineering practice. The partnership of institutions, with input and strong collaboration with industrial leaders, have developed an undergraduate manufacturing engineering option using the following strategy: a core curriculum emphasizing hands-on, practice-based activities, a **Learning Factory**, and strong relationship with industrial partners. The core curriculum, or option, consists of three elective courses - complemented by existing courses at each institution - that span the undergraduate curriculum and which, upon completion, will develop in the students many of the skills employers value.

The basic courses are described in Table 1.

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1 ***Engineering Education Issues: Report on Surveys of Opinions of Engineering Deans and Employers of Engineering Graduates on the First Professional Degree,*** NSPE Publication No. 3059, November, 1992.

2 For details see ***The Learning Factory - A new approach to integrating design and manufacturing into engineering curricula***, John S. Lamancusa, Jens E. Jorgensen, José L. Zayas-Castro, and Julie Ratner, 1995 ASEE Conference Proceedings

Table 1: NSF-MEEP Course Description

Course/Department	Description
Product Dissection/Mechanical Engineering (freshman level)	Hands-on dissection exercises to develop in students the ability to understand a machine/product in not only its functionality, but also in terms of its history, social impact, design methodology, marketing constraints, and customer needs
Entrepreneurship/Business Administration (sophomore level)	Focuses on the process of starting, financing and managing a business, and management of existing enterprises. Problem identification, prototypes.
Concurrent Engineering/Industrial Engineering (sophomore/junior level)	Interdisciplinary student teams follow-up on new product ideas developed in the entrepreneurship course to fine-tune designs, further develop prototypes and demonstrate its manufacturability and economic feasibility. Product life-cycle issues.

This academic year, the core curriculum/option is being pilot tested at the three institutions, and will be fully implemented in academic year 1996-97. The courses will be shared to other institutions by traditional as well as electronic means (Internet, CD-ROM).

The Need to Develop the Manufacturing Option for Chemical Engineering

Although the MEEP core curriculum is open to any engineering student, it is more focused on manufacturing engineering from the point of view of product engineering and traditional manufacturing processes (mechanical, electrical and industrial engineering outlook, not continuous, chemical processes). This, together with the fact that there is a strong presence of chemical and pharmaceutical manufacturing industries in Puerto Rico, motivated a team of faculty members from the Department of Chemical Engineering at UPRM to make the option more attractive to both chemical engineering and other engineering students that might end up working in the chemical process/pharmaceutical industry.

In May of 1995, the Procter and Gamble Foundation granted the Chemical Engineering Department a three-year curriculum grant to expand the MEEP manufacturing option for chemical engineering, one of four grants in the nation.

The Manufacturing Option for Chemical Engineering: the P&G Project

The thrust of the P&G project is the design of two new courses and the re-engineering of the capstone design to complement those developed by the NSF-MEEP team and those existing courses at the College of Engineering. The ChE Manufacturing Option suggests basically two sequence of courses: a general option and a plastics processing option, described in Table 2. While these two paths have already been identified, it is envisioned that the option can be tailored to each student's interests.

Table 2: Undergraduate Chemical Engineering Manufacturing Options*

General Option	Plastics Processing Option
Product Dissection (ME 3810)	*Product Dissection (ME 3810)*
Chemical Manufacturing Processes (ChE xxxx)	Polymer Chemistry (Ch 5165)
Manufacturing Processes (ME 4055)	Plastics Technology (ChE 4016)
Entrepreneurship (BA 3100)	**Plastics Processing (ChE xxxx)**
Concurrent Engineering (IE 4810)	Probability & Statistics for Engineers (IE 4010)
Process Design II (ChE 5022)	Process Design II (ChE 5022)

** NSF-MEEP courses in italics.* **P&G (new) courses in bold.**

Manufacturing Option Curriculum Focus & Courses' Description

Focus

As mentioned before, the manufacturing option for chemical engineering focuses in complementing existing and MEEP courses, while providing students with basic concepts and skills geared to the Puerto Rican chemical/pharmaceutical manufacturing industry.

The focus of this manufacturing option is its interdisciplinary nature that stresses a balance between science and industrial practice. Some of the highlights of the program are discussed hereinafter:

- The option includes courses in each year of undergraduate study, complementing traditional courses, and providing a **continuity** throughout the engineering program.
- The option includes courses from at least 5 departments: chemical engineering, industrial engineering, mechanical engineering, business administration and chemistry, as described in the options in Table 2. Courses from other departments can be taken in custom-made manufacturing options.
- The courses, which emphasize hands-on, practice-based experience for the students, will be carefully designed and supported by learning activities at the **Learning Factory** and through strong relationships with industry (projects, field trips, experts in the classroom, etc.). This laboratory, housed in the Industrial and Chemical Engineering Departments - supported by other satellite labs throughout Campus - has four real-life production lines available for student hands-on experiences:
    - assembly line (PVC pencil holder)
    - injection molding
    - surface mount technology (SMT)
    - tablet manufacturing
- All courses in the option will integrate the development of the **basic skills** identified as valued by employers [e.g., problem-solving, teamwork, and communication] and on business practice, economics, quality, marketing and management. The template for course development, which is shown in Table 3, includes objectives (content and skills), learning activities (lectures, hands-on activities, field trips, etc.) and assessment.
- The courses will use **novel learning and teaching activities**: these are not the typical "lecture, homework, quiz, test - type course". The courses will use team teaching, cooperative learning, hands-on activities and other non-traditional learning/teaching strategies documented as being successful in enhancing student learning.

- **Assessment** of the courses' outcomes has been given special attention. It will achieve several purposes: make aware the learner as well as the teacher the outcomes of the learning experience and how performance is going to be evaluated, facilitate the re-engineering of the course strategy, and document outcomes for outreach purposes.

Table 3. Course Template

Module	Objectives	Skills	Learning Activities	Assessment

- Industrial involvement will primarily be channeled through the ***Chemical Engineering "Konsortium"***, an advisory board which provides strategic guidance, assess performance and facilitate student and faculty projects, as well as donations in equipment, time and money.

Courses' Description

Chemical Manufacturing Processes

An introduction to the chemical process industries and the invention of processes for the large scale processing of materials such as chemicals, petroleum products, food, drug and wastes. Discussion of chemical process steps, the transformation of raw materials into desired end products, process flow diagrams, processing equipment, optimum solution and schematic representation of physical and chemical processes interconnections to carry out the overall transformation, evaluation of economic performance of different manufacturing options, evaluation of environmental, health, and safety criteria involving different manufacturing steps. Students will work in teams and will interact with industrial partners for special projects, participate in field trips, and other learning activities. Oral presentations and written reports will be required.

Plastics Processing

This course will balance fundamental understanding of plastics processing conversion processes and technology to actual practice in the polymer processing industry. It will highlight key aspects of the process including: materials, thermodynamics, fluid technology, control and tool/part design. Some of the conversion processes to be covered are: extrusion, blow molding, injection molding, composites processing, thermoforming, resin casting, recycling, equipment and tooling. The success of this course will depend heavily on partnerships between student teams and industrial experts. Students will form teams, communicate with industrial experts and report results to the class and each company involved. Factors such as economics, environment and safety will be included, and students will have the opportunity to play significant roles in organizing, planning and directing the learning process. The professor will serve as coach, coordinator, evaluator and cheerleader.

Chemical Engineering Process Design 2

The main objective of the course is the application of principles of economic evaluation, cost estimation, mathematical techniques, and simulation to the chemical engineering design process and/or equipment. The students will be able to practice the theory of chemical plant design based on a standard plant design project. It includes working at different phases to produce a **Preliminary Design Package** and a corresponding **Capital Appropriations Request** using a computer aided design (CAD) and plotter system and standard chemical engineering simulation packages. The work will be performed dividing the responsibilities in teams of 3 to 5 students acting as an engineering team with a rotating team leader. Some of the projects will be from industry. The teams will visit industrial sites to obtain the necessary information and will work together with engineers.

At the end of the semester the students will make a final presentation to the industrial sponsor using state-of-the-art presentation technology.

This course will be pilot-tested in January of 1996.

Conclusions

Although this is the first year of the project, the design and implementation of this interdisciplinary undergraduate manufacturing engineering option for chemical engineering is already creating much interest within faculty, students and industrial partners. It has the full support of the ChE Department administration - both the Chairman and the Associate Chairman are part of the team! The new and re-engineered courses are to be pilot tested next academic year (96-97) and the option fully implemented academic year 97-98. It is expected that the courses will be ready to be exported after the final fine-tuning, in academic year 97-98. It is expected that their dissemination (course material and resources) will be through traditional as well as electronic means (CD-ROM and WWW).

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