The Pharmaceutical Engineering Program at NJIT: a Working Example of Industry-University Collaboration in a Novel and Fast-Growing Engineering Field

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Abstract — This article describes the newly established Master of Science Program in Pharmaceutical Engineering, which was developed at the New Jersey Institute of Technology (NJIT) in collaboration with industrial participants, and at the request of New Jersey-based pharmaceutical companies. The primary objective of the program, which started in January 2002, is to educate professionals and provide them with the skills required to work in the pharmaceutical field, with particular emphasis on the engineering aspects of drug manufacturing, pharmaceutical production, pharmaceutical development, and pharmaceutical operations. To achieve this goal a 30-credit program of study structured along two different tracks was established. The two tracks have a common 9-credit core. Each track has an additional 9-credit track-core. Each track has 12 credits of electives selected by the student in consultation with the program advisor. The first track, called the Pharmaceutical Production and Development Track, is focused on those operations, such as chemical synthesis and separations, required in the development and manufacturing of active pharmaceutical ingredients. The second track, the Pharmaceutical Operations Track, is oriented towards the unit operations commonly found in the pharmaceutical processing of solid and liquid dosage forms. The program has been extremely successful so far, attracting full-time and part-time students with a variety of backgrounds, including many professionals who currently work at local major pharmaceutical companies. Local industries have significantly contributed to the program in terms of financial support, course instructors, lecturers, donated equipment, and access to employees as potential students.

Index Terms — Pharmaceutical Engineering, Chemical Engineering, Pharmaceutical Industry, Pharmaceutical Companies, Master Degree, Graduate Studies, New Jersey Institute of Technology, NJIT.

INTRODUCTION

New Jersey Institute of Technology (NJIT) is New Jersey’s public technological research university, with an enrollment of more than 8,800 students per year and approximately 1,900 degrees granted annually from the baccalaureate to the Ph.D. in an array of engineering and technology disciplines, computer and information science, architecture, management, applied science, mathematics and biotechnology.

New Jersey is geographically at the heart of the nation’s pharmaceutical industry, and NJIT is located at the national epicenter of industrial pharmaceutical research and development. In fact, NJIT’s campus is located within miles of the headquarters and major facilities of 21 of the world’s leading pharmaceutical industries, greatly facilitating industrial interactions and providing a fertile ground for student career development.

Over the years, NJIT has developed strong ties with its industrial base and especially with the local pharmaceutical companies. This has resulted in a number of industry-university cooperation activities, including but not limited to, industry-sponsored research projects, collaborative projects of industrial relevance sponsored by federal and state agencies, establishment of industry-university research centers, student internships and co-op activities at local companies, student placement, consulting opportunities for NJIT faculty in their specific range of expertise, opportunities for industry professionals to teach courses, lecture classes, and co-advice graduate students together with NJIT faculty members, as well as serve on university industrial advisory boards and steering committees.

Historically, industrial cooperation with pharmaceutical companies in engineering fields has involved a number of academic departments at NJIT, and especially those departments that have greater affinities for the core activities of the industry, such as mechanical and industrial engineering, and especially chemical engineering.

Given NJIT’s location and the already strong interactions with local companies (and especially pharmaceutical companies) it is only natural that the industry needs would be reflected in the research and educational activities that are most appropriate for those industrial sectors. As far as NJIT’s chemical engineering department is concerned, this has resulted in the establishment of a number of research projects in areas, such as membrane technology, nanotechnology, mixing, and
crystallization, just to mention a few, that are especially relevant for the pharmaceutical industry. In many cases, those students who have worked on those projects were eventually hired by pharmaceutical companies. On the educational front, efforts were also made to educate professionals who not only had a strong background in the fundamentals, but were also specifically prepared for technical careers within the industry.

The most tangible of these efforts has resulted in the establishment of a Pharmaceutical Engineering program, leading to a Master Degree in Pharmaceutical Engineering (www.njit.edu/che/pharme/). The objective of this article is to describe such program in some detail, and discuss the professional opportunities that it will create, as well as the challenges that had to be overcome to establish it and further develop it.

THE PHARMACEUTICAL INDUSTRY AND NEW JERSEY

The pharmaceutical/medical technology industry is the largest manufacturing industry in New Jersey. New Jersey is home to the headquarters of more global pharmaceutical and medical technology companies than any other state in the country, or any single country throughout the world. Some of the world’s largest pharmaceutical companies have their U.S. or world headquarters in New Jersey, including Aventis (Parsippany, NJ), Bristol-Myers Squibb (Lawrenceville, NJ), Hoffmann-La Roche (Nutley, NJ), Johnson & Johnson (New Brunswick, NJ), Merck (Whitehouse Station, NJ), Novartis (East Hanover, NJ), Schering-Plough (Kenilworth, NJ) and Wyeth (Madison, NJ). All these locations, including Pfizer, whose headquarters is in New York, NY and who recently acquired Pharmacia (Peapack, NJ) and Warner Lambert (Morris Plains, NJ), are only a few miles from NJIT’s campus. Figure 1 shows the location of the major pharmaceutical facilities in New Jersey

In order to understand the role of the pharmaceutical industry in the U.S. and especially in New Jersey it is useful to produce some data. According to statistics compiled by the HealthCare Institute of New Jersey (HINJ), of the 17 new drugs approved by the U.S. Food and Drug Administration (FDA) in 2002, 7, i.e., more than a third, came from New Jersey based pharmaceutical companies [1]. In 2001, 15 of the 24 newly approved drugs were developed by New Jersey based companies.

According to Bob Franks, president of the HINJ, "New Jersey's pharmaceutical industry allocates more dollars to research and development than any other industry in the state. The fact that our research-based companies developed a third of all new medicines demonstrates why investment in R&D is so critical. As a result of these new drugs, millions of Americans - and people around the world - will benefit." [1]

Employment at New Jersey pharmaceutical companies was 66,024 in 2001. The 2000 figure was 62,937. i.e., 5% higher than the previous year, and 9% greater than the 1999 figure. About one-quarter of the 66,024 employees worked in research and development. The industry employs workers who are well trained and highly educated. The average compensation (including wages, salaries, bonuses and overtime but excludes benefits) was at $85,579 in 2001, and in that same year, the pharmaceutical and medical technology industry had estimated economic impact on New Jersey's economy of $13.4 billion.

According to Fred Hassan, CEO of Schering Plough and Former CEO, Pharmacia & Upjohn “New Jersey was the jewel we were looking for... [i]t is truly the nation’s medicine chest, the center of gravity of the pharmaceutical industry.” [2]

ESTABLISHMENT OF THE MASTER DEGREE PROGRAM IN PHARMACEUTICAL ENGINEERING

In the Fifth Annual Systemwide Accountability Report [3], the New Jersey Commission on Higher Education (NJCHE) stated that “As a growing technology hub, a leader in...pharmaceutical industries... New Jersey has a significant need for degree programs to prepare a high-tech workforce.” The recent efforts of NJIT in this field have been aimed at closing this gap in order to benefit not only New Jersey-based companies, but also the pharmaceutical industry in general.

The pharmaceutical industry needs not only scientists but also qualified engineers to bring new drugs to the market. For this reason, pharmaceutical companies have historically recruited at NJIT to hire B.S., M.S. and Ph.D. engineering students in general, and chemical engineers in particular, to work primarily in their development and manufacturing groups.
However, to better address the industry need for qualified engineers, in December 2001 NJIT established the first official Master Degree Program in Pharmaceutical Engineering in the State of New Jersey. The program, now in its third semester of existence, has grown substantially in a very short period of time, rapidly attracting a much larger number of students than initially anticipated (see Figure 2), including a large number of students currently working at local pharmaceutical companies. The enrollment in the program of professionals working full-time at pharmaceutical companies is further evidence of the need for this type of program.

It is expected that the program described here (one of a handful of such programs in the U.S.) will experience a very significant growth both in size and in its range of activities over the next few years, in response to the growing needs of the pharmaceutical industry for qualified engineering professionals.

**ROLE OF INDUSTRY IN PROGRAM DEVELOPMENT**

The NJIT program was developed in direct response to specific requests from industry. Before the program was established, an ad hoc Industrial Advisory Group including representatives from both the pharmaceutical industry and support organizations was formed to provide feedback and guidance.

Industry participation has been instrumental not only in the development of the program but also for its financial support, and the involvement of industry professionals in teaching courses and providing technical expertise. A number of local companies, including Schering-Plough, P.F. Laboratories, Novartis, and Torcon, provided initial funds to help establish the program. Others, including Bristol-Myers Squibb and Johnson & Johnson have contributed by providing instructors, lecturers, and equipment. Even more companies are expected to participate in the future.

The program also benefited from the input and the active involvement of experts from the pharmaceutical industry in the classroom, and in the advisement of students who conduct research work leading to MS in Pharmaceutical Engineering or Ph.D.’s in chemical engineering. Both programs have been generously supported by the pharmaceutical industry.

The interest of industry was further demonstrated by a number of financial grants culminating in a $250,000 grant by the Schering-Plough Foundation which was awarded to NJIT in 2002 for the sole purpose of further developing the Pharmaceutical Engineering MS Program. These grants are not to be confused with other industrial research grants specifically awarded to individual academic investigators at NJIT to conduct research of interest to the pharmaceutical industry in general, and to individual pharmaceutical companies in particular.

One of the most valuable aspects of the industrial participation in the program has been the involvement of industry professionals in the classroom. Because of the nature of the pharmaceutical industry, it was decided early on that the program must include courses which are critical to the formation of qualified pharmaceutical engineering professionals, but which are not typically incorporated in academic programs. Examples include validation, regulatory issues, and facility design courses. Most academic faculty do not typically have the experience and expertise required to teach such courses. Therefore, the involvement of qualified professionals from industry in the teaching of such classes has been instrumental to the development of a curriculum that is relevant to the industrial needs. Currently, a number of pharmaceutical engineering classes are taught or team-taught (in cooperation with regular faculty members) by adjunct professors who are working, or have worked for many years, in the pharmaceutical industry. In addition, most classes benefit from the extensive participation of lecturers from industry on particular topics of interest. The combination of traditional academic instructors and industrial speakers has been extremely valuable, as indicated by the very positive response of the students in class.

**PROGRAM OBJECTIVES**

The Master of Science Program in Pharmaceutical Engineering is an interdisciplinary program jointly developed by the Department of Chemical Engineering and the Department of Industrial and Manufacturing Engineering at NJIT. Information about the program is available at www.njit.edu/che/pharme/. The primary objective of the program is to educate professionals and provide them with the skills required to work in the pharmaceutical field, with particular emphasis on the engineering aspects of drug manufacturing, pharmaceutical production, pharmaceutical development, and pharmaceutical operations.
NIIT’s M.S. program in Pharmaceutical Engineering provides the intellectual climate and the necessary tools needed to prepare students for positions and career advancement within the industry, based on the rigorous technological requirements of this highly regulated work environment.

The program is designed to provide opportunities for specialization in such areas as pharmaceutical processing and manufacturing, validation and regulatory issues in the pharmaceutical industry, pharmaceutical facility design, pharmaceutical packaging technology, reaction engineering for pharmaceutical production, pharmaceutical separation processes, pharmacokinetics and drug delivery, molecular modeling for drug discovery, pharmaceutical synthesis, fluid mixing in the pharmaceutical industry, instrumental analysis, and industrial quality control.

**ADMISSION REQUIREMENTS**

In order to be admitted to the program applicants are typically required to possess an undergraduate degree in chemical engineering and have an undergraduate cumulative grade point average (GPA) of at least 3.0 on a 4.0 scale. Students with a mechanical engineering degree are also typically admitted without other conditions, although some may be required to take a graduate level course in transport phenomena, which counts towards the total number of credits necessary to receive the MS degree. Students with backgrounds in other engineering disciplines, such as industrial engineering, are also admitted to the program, although they may be required to take one or possibly two bridge courses (described below), which do not count toward degree credits, or the corresponding graduate level courses, which instead count toward degree credits.

Applicants with: (1) a science degree, (2) an engineering degree in a discipline other than chemical or, possibly, mechanical and industrial engineering (as indicated above), or (3) a GPA below 3.0 but at least 2.8, may be conditionally admitted to the program. Conditions involve completion of a bridge program designed on a case-by-case basis, and typically requiring taking extra bridge courses, as further explained below. These courses are not counted toward degree credit.

Submission of Graduate Record Examination (GRE) scores is encouraged in all cases, and required of those seeking financial support and those whose last prior degree is from an institution outside the United States. International students must also submit scores from the Test of English as a Foreign Language (TOEFL). According to university policy, a minimum TOEFL score of 550 (paper-based test) or 220 (computer-based test) is required.

The admission requirements described above can be partially relaxed for applicants with significant industrial experience in the pharmaceutical industry (in excess of five years). The admission requirements for such candidates are typically established on a case-by-case basis, and are determined through an interview with the prospective student and the submission of letters of support attesting the level of experience attained. It should be stressed, however, that this option is not often used in practice, since, although some candidates may have significant industrial experience, they may lack the fundamental knowledge that can only be acquired by taking some of the bridge courses and regular courses. Therefore, many industrial non-engineering students are required to take these courses, at least in the vast majority of cases.

**BRIDGE PROGRAM FOR NON-ENGINEERING STUDENTS**

The current Pharmaceutical Engineering Master program is strongly oriented toward the *engineering* component of “Pharmaceutical Engineering”. In addition, since the pharmaceutical industry is a chemistry-based industry a chemical engineering background was perceived to be the most appropriate to enter the program.

However, during the program development phase, the question was raised of whether to admit students with background in disciplines other than engineering in general, or chemical engineering in particular. This question is especially relevant for a pharmaceutical engineering program since the industry is heavily populated with scientists, such as chemists, pharmacists, and microbiologists, who have traditionally played a dominant role within the industry, and who occupy there key positions even in areas (such as development groups) in which engineers are traditionally predominant, at least in other industries. In the end, it was decided that the program would ultimately benefit from the presence of students with diversified backgrounds, provided that non-engineering students and engineering students with an engineering degree that did not offer courses in some of the areas critical to the program would be adequately prepared before entering the program. Therefore, the program was designed so that applicants with different backgrounds could be admitted. This was accomplished by establishing a bridge program that provides such students with the background required to enter the pharmaceutical engineering graduate program.

Depending on the background of the applicant this bridge program may consist of up to three (but generally speaking less, at least for students with engineering degrees) 3-credit courses (PhEn 500, PhEn 501 and PhEn 502) specifically designed to provide the students who need them with the necessary prerequisites to enter the program. Each bridge course covers a variety of subjects, but none of them counts toward degree credit. Some regular pharmaceutical engineering courses (e.g., PhEn 601 and PhEn 604) can be taken concurrently with the bridge program courses. Currently the following bridge courses are available:
• **PhEn 500 – Pharmaceutical Engineering Fundamentals I.** This course is intended for those students who do not have a background in differential equations, probability and statistics, and finance business mathematics. The course includes a review of calculus, and covers the fundamentals of ordinary differential equations (first order, linear, non-linear, second order, homogeneous and non-homogeneous), probability and statistics (probability models, normal distribution, statistical estimation, expected value; measures of dispersion; measures of central tendency, application of sampling distribution theory, determination of sample size, linear regression analysis, least square method; estimation of parameters, statistical inference), and finance business mathematics (interest/compound interest, annuities, sinking funds, amortization, leasing and capital expenditure). All these topics are applied to pharmaceutical engineering problems and illustrated through pharmaceutical engineering examples, such as drug excretion and AUC.

• **PhEn 501 – Pharmaceutical Engineering Fundamentals II.** This course covers the fundamentals of pharmaceutical engineering calculations related to material and energy balances (for steady and unsteady, non-reactive and reactive systems) applied to pharmaceutical facilities and systems; estimation of thermophysical properties, phase and reaction equilibrium; and chemical kinetics and basic reactor design.

• **PhEn 502 – Pharmaceutical Engineering Fundamentals III.** The course covers the fundamentals of fluid mechanics (fluid statics, viscosity, continuity equation; equation of motion; equation of energy, laminar flow, turbulent flow; Reynolds number; f factor, average velocity, pumps and hydraulic systems, flow past immersed objects), heat transfer (conductive, convective, and radiative heat transfer, energy balances, heat exchangers), mass transfer (diffusion, convective mass transfer; mass transfer coefficients, mass transfer applications to vapor-liquid, liquid-liquid and solid-fluid separation processes and equipment) and the design of unit operations involving these principles.

### DEGREE REQUIREMENTS

The Master of Science in Pharmaceutical Engineering is a 30-credit program structured along two different tracks. Applicants have to specify the track they seek admission to. The two tracks have a common 9-credit core. Each track has an additional 9-credit track-core, as described below. Each track has 12 credits of electives selected by the student in consultation with, and subject to, the approval of the program advisor.

Students have the option of fulfilling 6 of the 12 credits of electives by doing a Master’s Thesis. The thesis option is primarily but not exclusively meant for full-time students. Full-time students receiving support (full or partial) must complete a Master’s Thesis.

Students are certified for graduation if they maintain an overall cumulative grade point average of at least 3.0, as well as a grade point average of 3.0 in the required six core courses.

### PROGRAM OF STUDY

The program has two tracks, i.e.:

- **Pharmaceutical Production and Development Track**
- **Pharmaceutical Operations Track**

The required core courses depend on the track selected, although the total number of core courses (6) and corresponding core credits (18) are the same for both tracks, and 3 of the core courses (9 credits) are common to both tracks. A number of concentration areas are available within each track.

### Course Requirements

Students have to complete the following course requirements in order to complete the 30 credits necessary to graduate.

- Three (3) core courses (3 credits each) common to both tracks (9 credits total), as follows:
  - PhEn 601 Principles of Pharmaceutical Engineering
  - PhEn 603 Pharmaceutical Processing and Manufacturing
  - PhEn 604 Validation & Regulatory Issues in the Pharmaceutical Industry

- Three (3) additional core courses (3 credits each) specific to the track selected (9 credits total), as follows:
  - **Pharmaceutical Production and Development Track**
    - PhEn 612 Pharmaceutical Reaction Engineering
    - PhEn 614 Pharmaceutical Separation Processes
    - PhEn 618 Principles of Pharmacokinetics and Drug Delivery
  - **Pharmaceutical Operations Track**
    - EM 602 Management Science
    - PhEn 602 Pharmaceutical Facility Design
PhEn 605  Pharmaceutical Packaging Technology

- Four (4) additional elective courses (3 credits each) selected from the list of available courses (12 credits total; see below).

**M.S. Thesis Requirements**

Students who are required, or choose, to do a thesis must take 6 credits of PhEn 701 (Master’s Thesis) in lieu of 6 credits of elective courses.

**PHARMACEUTICAL ENGINEERING COURSE DESCRIPTION**

A number of pharmaceutical courses (having the “PhEn” designation) have already been developed and more will be created over the next semesters. The courses already developed include all the core courses, and are briefly described here.

- **Principles of Pharmaceutical Engineering – PhEn 601.** This course provides an overview of the pharmaceutical industry, including basic information about drug discovery and development, FDA requirements and approval processes, drug dosage forms, and the role of key operational units in drug manufacturing processes. This course enables the students to: understand the role of the pharmaceutical industry in the global market and its implications; learn the fundamentals of the drug development cycle and the investment required to bring a drug to market; learn the most important drug manufacturing processes and the key elements of dosage formulation.

- **Pharmaceutical Facility Design – PhEn 602.** This course provides instruction in design of state-of-the-art pharmaceutical facilities for both manufacturing and R&D, by identifying key functional requirements and design concepts necessary to pharmaceutical processes. Interdisciplinary training will be provided in appropriate areas of facility design.

- **Pharmaceutical Processing and Manufacturing – PhEn 603.** This course covers state-of-the-art pharmaceutical processing, identifying underlying chemical process engineering principles and providing quantitative approaches to drug product manufacturing process design and optimization. It also provides interdisciplinary training in pharmaceutical engineering focusing on issues relating to issues in quality testing, drug absorption and bioavailability.

- **Validation and Regulatory Issues in the Pharmaceutical Industry – PhEn 604.** This course is focused on the development of a working knowledge of the Federal Code of Regulations and its impact on the pharmaceutical and allied industries. The history of the Federal Government’s regulation of the pharmaceutical industry is studied. Also covered is the industry’s response and the methodologies it uses to comply with these regulations.

- **Pharmaceutical Packaging Technology – PhEn 605.** This course focuses on developing a working knowledge of the machinery and unit operations used in transferring a drug substance in the bulk final form to a finished product ready for sale to the consuming public. Packaging of both liquid and solid forms in various types of delivery containers such as vials/ampoules, blister packs, individual packets, bottles, pouches and syringes is examined. The cleaning, sterilization and scaling/capping required for each dosage form is discussed, as well as freeze-drying, tableting, capsule filling, and form/fill/seal, and the proper labeling of final drug forms.

- **Pharmaceutical Reaction Engineering – PhEn 612.** This course examines a variety of reactions typically encountered in the pharmaceutical industry, including single/multiple phase (e.g. crystallization), fine chemical synthesis, enzymatic, bio-reactions (fermentation), and others. The course then focuses on quantitative pharmaceutical reactor design and scale-up issues.

- **Pharmaceutical Separation Processes – PhEn 614.** This course will cover separation processes in general and pharmaceutical separations in particular. Specific processes to be studied include distillation, extraction, crystallization, adsorption, ion exchange, chromatography, moving bed processes, electrophoresis, freeze-drying, microfiltration/ultrafiltration, reverse osmosis, and pervaporation. Pharmaceutical manufacturing flow sheets will also be examined.

- **Principles of Pharmacokinetics and Drug Delivery – PhEn 618.** The course covers the basic principles of pharmacokinetics, including drug transport, parenteral and enteral routes of drug administration, and factors affecting drug absorption, distribution, and metabolism. Mathematical pharmacokinetic models and drug delivery processes are also presented and quantitatively studied. The objective of this course is to study of the absorption, transport distribution, metabolism, and excretion of drugs and metabolites in the human body.

**CONCENTRATION AREAS**

Students are free to select their electives from an extensive list of available courses in consultation with, and subject to, the approval of the program advisor. However, in order to acquire deeper knowledge in a specific area of interest students may choose to take three of the four elective courses grouped in one of the following “concentration areas”.

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International Conference on Engineering Education  
Concentration Areas for the Pharmaceutical Production and Development Track

- **Drug Synthesis**
  - PhEn 620 Molecular Modeling for Drug Discovery
  - PhEn 616 Pharmaceutical Synthesis

- **Pharmaceutical Operations**
  - PhEn 602 Pharmaceutical Facility Design
  - PhEn 605 Pharmaceutical Packaging Technology
  - PhEn 702 Selected Topics in Pharmaceutical Engineering

- **Biochemical**
  - ChE 628 Biochemical Engineering
  - Chem 673 Biochemistry
  - BME 672 Biomaterials

- **Particle Technology**
  - ME 664 Experiments and Simulations in Particle Technology
  - ME 624 Microlevel Modeling in Particle Technology
  - Chem 644 Fundamentals of Adhesion

- **Fluid Technology**
  - ChE 6XX Fluid Mixing in the Pharmaceutical Industry
  - ChE 645 Fundamentals of Rheology
  - ChE 624 Transport Phenomena I

- **Quality Control**
  - Chem 661 Instrumental Analysis
  - Chem 664 Advanced Analytical Chemistry
  - IE 672 Industrial Quality Control

- **Information Technology**
  - CIS 505 Programming, Data Structures, and Algorithms
  - CIS 610 Data Structures and Algorithms
  - CIS 631 Data Management System Design

Concentration Areas for the Pharmaceutical Operations Track

- **Quality Control**
  - IE 672 Industrial Quality Control
  - IE 673 Total Quality Management
  - IE 605 Engineering Reliability

- **Pharmaceutical Production**
  - PhEn 612 Pharmaceutical Reaction Engineering
  - PhEn 614 Pharmaceutical Separation Processes
  - PhEn 618 Principles of Pharmacokinetics and Drug Delivery

- **Manufacturing Operations**
  - MNE 602 Flexible and Computer Integrated Manufacturing
  - MNE 655 Concurrent Engineering
  - MNE 601 Manufacturing Systems

- **Systems**
  - IE 604 Advanced Engineering Statistics
  - IE 621 Systems Analysis and Simulation
  - IE 704 Sequencing and Scheduling

- **Logistics**
  - EM 640 Distribution Logistics
STUDENT INVOLVEMENT IN RESEARCH AND RESEARCH OPPORTUNITIES

In addition to taking courses, students have the opportunity to work, one-on-one, with faculty members in chemical engineering and chemistry who have already conducted research in pharmaceutical engineering and chemistry, on research projects in areas of common interest, allowing maximum flexibility for independent work, and providing students with valuable research experience. Students have the option to complete a Master’s thesis.

Current research areas of interest to the pharmaceutical industry include molecular modeling in drug discovery, chiral synthesis, process engineering for kinetic resolution of enantiomers, mixing phenomena, modeling of crystallization processes, fast chemical reactions, membrane technology, particle and nanoparticle technology, sensors, neural network applications to pharmaceutical reactors, biomaterials for tissue engineering and drug delivery, supercritical fluids for organic synthesis, and polymer technology for pharmaceutical application. Equipment is already available to conduct pharmaceutical engineering and chemistry research. Additional research equipment is expected to become available through research grants, industry donations, and cooperation with industrial partners.

Qualified, research oriented students have the option of continuing their studies at NJIT by pursuing a Ph.D. in chemical engineering, industrial engineering, chemistry, or related disciplines. The NJIT-Industry Collaborative Ph.D. Program allows greater flexibility to industrial students who are interested in pursuing their Ph.D. while working full-time in industry.

CONCLUSION

The Master Degree Program in Pharmaceutical Engineering that has been recently developed at NJIT is an important step in the formation of a cadre of engineering professionals that the industry currently needs and in the education of professionals who need to possess the skills required to work in the pharmaceutical engineering field. In the end, these activities, and others to follow, will contribute to generate the workforce required to satisfy the needs of the growing and highly successful pharmaceutical industry and make it more competitive, while reinforcing NJIT’s role as the state’s premier, public, technological university.

ACKNOWLEDGEMENT

The financial support of a number of companies including Schering-Plough, Bristol-Myers Squibb, P.F. Laboratories, Novartis, and Torcon is gratefully acknowledged.

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