JOINT GOVERNMENT - INDUSTRY - ACADEMIA PROJECTS INVOLVING UNDERGRADUATE STUDENTS

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Abstract *- In the senior year, chemical engineering students at Widener University are required to take two technical elective courses in addition to the rest of their regular courses. If a student pursues an independent study project with industry and a faculty member, then this project will usually count as a technical elective. If a student wishes to perform a work-study project then this will not count as credit but will provide the student with the opportunity to work directly with a professor or an industrial advisor on a contractual basis. Details on examples of both cases are presented for previous work and for research that is on-going this semester at Widener University.*

INTRODUCTION

The curriculum of the Department of Chemical Engineering along with hot links to the course files may be found on the department's home page (http://www2.widener.edu/~chemengr). The senior year of the curriculum is summarized in the table below (Table I).

Table I
Senior Year Curriculum
Department of Chemical Engineering

Fall Semester

Course	Design Content
Senior Project	high
Control Systems	moderate
Engineering Economics	low
Process Design Methods	high
Chem Eng Laboratory II	moderate
Physical Chemistry Laboratory	low

Spring Semester

Course	Design Content
Senior Project	high
ChE Kinetics and Reactor Design	moderate
Process Design	high
Technical Electives	varies (usually high)

In previous studies (1,2) on the inclusion of design in the chemical engineering curriculum and the use of high-end software, emphasis was placed on how to include industrial issues within the content of the specific courses. In this current discussion, the emphasis is on the structure that can either:

a. enable the student to get course credit for research performed with a professor and under the mentoring of an industrial partner
b. provide a work study project in which the student is an employee of the industrial partner and performs research at the school

Given the ABET 2000 criteria for accreditation and the mission of the chemical engineering program (Table II), these existing projects and emphasis are in concert with the theme of the new standards. The assessment is immediate, comprehensive, and from a high level, external source.

Table II
Mission Statement - Chemical Engineering Program

The mission of the chemical engineering program is to provide a personalized environment in which students receive a broad education in the basics of chemical engineering, while interacting with the colleagues and faculty that exist at a comprehensive university. As such, students develop a desire for life-long learning and professional development. The program strives to produce chemical engineers with the skills to excel, in an honorable fashion, in industry, government, or academia. To fulfill this mission, the objectives of the program are:

a. to provide a broad base of knowledge in the fundamentals of chemical engineering
b. to make available for students the following options:
  i. dual majors or minors in chemistry, mathematics, or biology
  ii. advanced learning via independent study
  iii. interaction with industry and other institutions via co-operative education, internships, or special programs
  iv. undergraduate research with faculty, industry, other universities, and/or government agencies

Feedback from the assessment can be funneled immediately back into the educational organization, or directly into the instruction if appropriate. Additionally, students must be adequately prepared in order to undertake such an effort in their senior year. Students need to have the analytical tools, interpersonal skills, organizational ability and enthusiasm to

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successfully complete an intensive project and not let their grades or other activities suffer.

The advantages to the industrial/government partner are obvious. They have access to bright students desiring to perform well and working at a fraction of the cost of a regular employee, an academic setting with many resources, established laboratories (computing and experimental) and infrastructure, and the participation of the professor. The advantages are so numerous that the academic advisor must structure the relationship that the students are provided with the proper mentoring by the outside partner. Indeed, it takes a special kind of partner to consider the student as something other than a means to an end.

HISTORICAL PROJECTS AT WIDENER UNIVERSITY

Over the past several years, independent study and work study have become very popular among undergraduates. At Widener University, in the Department of Chemical Engineering, the projects began several years ago with PECO Nuclear. Students were involved in a variety of projects from the simulation of the cooling water system using commercially available general process simulators to the assessment of turbine performance which involved hands-on work. The industrial partner was very satisfied with the work, the students received mentoring from professionals at the plant, and had the opportunity to visit the facilities and see the organization and the equipment in operation as they would upon being employed.

Following on the success of the initial PECO projects, independent study and work-study projects have been developed and successfully completed with a variety of other companies and government agencies (see Table III for this year's listing of projects). These projects have all fit the criteria established by the university for work-study or independent study and have all provided the opportunity for a close mentoring relationship with professionals from industry.

Support for these projects has come from government grants, through the SBIR program or directly from the company involved with the project. The response of the industry has been very favorable because of the high level of performance of the students and the open nature of the faculty and university administrators in accepting such involvement with the students.

Table III
1999-2000 Undergraduate Research Projects
Using Independent Study or Work-Study Criteria

Agency	***Project Scope***
PECO	*Simulation of the Liquefied Natural Gas Works in Suburban Philadelphia* [senior students simulate the dual cycle liquefied natural gas process using the HYSYS general process simulator; this project is described further below]
PTC, Inc.	*Development and Operation of a Batch Reactor for Environmental Applications* [Students test the application of Phase Transfer Catalysis (PTC) in a dilute aqueous system; this technology is described further below]
LRSM (U of PA)	*Determination of the Morphology of Freeze Dried Collagen Substrates* [In collaboration with the University of Pennsylvania, students produce and characterize the structure of porous collagen structures]
SCS, Inc.	*Remediation of Intractable Waste Streams Using Novel Processing* [Work-study students are studying the remediation of various polluted aqueous streams]
NASA	*Study of the Thermodynamic Cycles Available on Space Station or the Mars Orbiter and Lander* [Work-study students and faculty are simulating the various utility systems available on the space station and on long term spacecraft]
NRL	*Production of Collagen Substrates for Remote Biosensing* [Senior project and work-study students and faculty are developing the technology for the manufacture of porous collagen substrates]

<u>Example 1 - Phase Transfer Catalysis Project</u>

In Fall, 1999, a joint research project was initiated between faculty and students from the Department of Chemical Engineering, Widener University, and the Phase Transfer Catalysis (PTC) Value Recovery Joint Venture. PTC is funded under an SBIR Phase I grant from the U.S. Department of Energy. The project involves the development of the traditional phase transfer catalysis in environmental clean-up. Experiments are performed in a hood in a 500 ml stirred reactor (Figure 1).

Results are monitored by the compositional analysis of the organic phase performed on a HP-5890 Gas Chromatograph (GC). Students run the experiments and the GC analyses; keeping track of raw material and waste inventories. The key to the practicality of this technology is to have reaction and mass transfer rates high enough to make the equipment economically viable. The students develop the experiment, analyze the data, as well as make conclusions and scale-up suggestions.

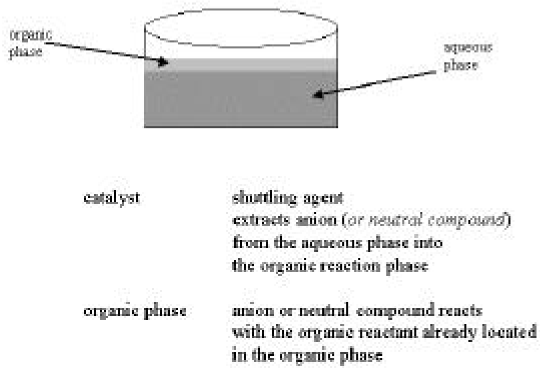


Figure 1 Experimental Set-up Consisting of a 500 ml three port glass vessel: one port is used for the mixer, one for the temperature control, and the other for the sampling

If the rate is significant at low temperatures (as planned in the experiment), then the process has potential commercial viability for the remediation of aqueous waste streams.

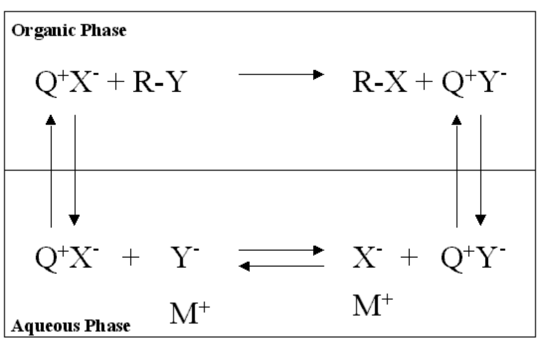


Figure 2 Reaction Mechanism
Q+, quaternary ammonium salt;
MX, phenol; RY, benzyl chloride

In the performance of their research, students are treated as employees and hence are paid by the small business with grant funds. From the university standpoint, the department receives a grant, as stated in the SBIR proposal for use of the laboratory and other facilities. The students do not receive any credit towards their graduation requirements and must organize their time effectively enough to incorporate their research within their senior year schedule.

Many companies around the world are using the concept of phase transfer catalysis for their production processes, but this research may represent the initial testing of an environmental application. This affords the students the opportunity to participate in cutting-edge research while developing a sense of good environmental stewardship.

In a nutshell, the technology (3,4,5,6) offers a novel method for recovering organic chemicals from dilute aqueous streams by moving the organic material from the aqueous phase to the organic phase via a phase transfer reaction. A quaternary ammonium salt that establishes a bridge via equilibrium between the two phases (see Figure 2) facilitates the pollutant transfer. As such, the aqueous stream is remediated and the potential pollutant is recovered as a valuable molecule in the organic phase.

Experimental Goal - PTC

The goal of the experiments is to ascertain the viability of phase transfer catalysis in environmental remediation. As such, the students are confronted in a "real way" with many of the issues they have been studying in the classroom:

- the rate of reaction as a function of temperature
- reaction time
- impact of mixing and reagent compositions
- experimental set-up and design/data analysis

The project has worked successfully from both an academic and research standpoint. The students performed the experiments and analyses effectively; the chemistry, which is step-out in nature, was demonstrated to be efficacious in environmental remediation.

Example 2 - Naval Research Laboratories - Production of Collagen Substrates for Remote Biosensing

Senior project and work-study students and faculty are developing the technology for the manufacture of porous collagen substrates.

In the emerging field of the cell culture of attachment dependent organisms, new techniques for immobilizing cells has lead to the development of novel host substrates. One such substrate is produced from Type I Bovine Hide Collagen (BHC). This material can be tailor-made to the type of cell and processing equipment that is used. Processing in fermenters usually takes the form of continuous stirred tank reactors or fluidized bed bioreactors.

For the NRL project, students manufactured collagen matrices to fit stem and neural cell viability requirements. Essentially, the pore structure must be open enough for the cells to populate rapidly and attach to the collagen surface, but not too big that the cells get washed out. Once populated, the cells are exposed to a variety of environments including toxic agents. When environmentally stressed, the cells fluoresce, thus allowing for detection by an optical sensor (7).

Stem and neural cell culture technology is also very important for the emerging field of organ regrowth and tissue engineering. In these applications the collagen matrix is used as a template for the regrowth of organs by the implantation of the appropriate cells: in the case of liver regrowth, hepatic cells (8) are implanted onto a collagen template.

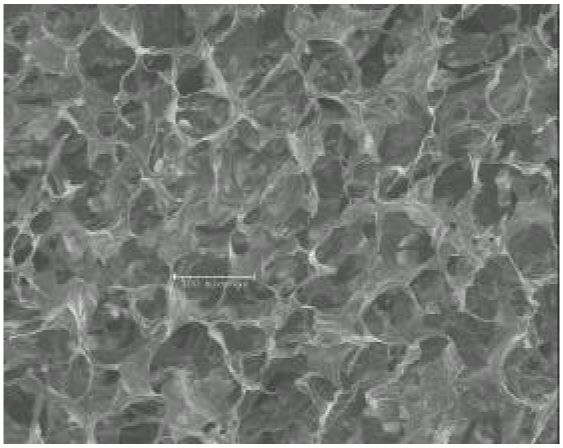


Figure 3 Example of the collagen matrix, showing pore sizes of 50 + microns. Astrocytes are about 10-15 microns wide but have ganglia that stretch twice that distance or more. Consequently, in order to achieve good population, the pores must be large enough and have a good amount of surface area for attachment.

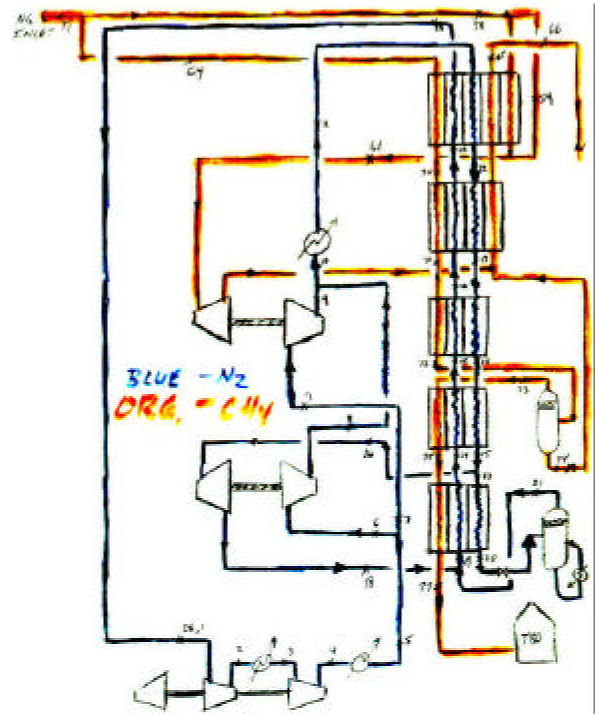
Students used the LRSM facility at the University of Pennsylvania to visually assess the production technology (see Figure 3). The NRL also provided cell culture data (rate of cell growth, cell viability, nutrient consumption, etc.). The results of the research have been the establishment of the protocols for the production and characterization of collagen substrates. Parameters were developed that help in the overall production process in the tailoring of the substrates for the particular cell line.

Beyond the success of the project in developing the production and characterization technology, the students also gained experience in teamwork. The nature of the collaboration between the NRL, U Penn, and Widener U is very productive. The opportunity to interface with researchers at other institutions as well as the government laboratory is significant for all students and unique for undergraduate students.

Example 3 - Advanced Modeling of an LNG Production Facility

As part of an independent study project which will count as a technical elective, students have demonstrated the use of HYSYS, a general process simulator (software package) for a liquefied natural gas facility (LNG). Students converted the piping and instrumentation diagrams into a simplified process flow diagram (Figure 4) that could then be simulated using the HYSYS simulation package. The process consists of a natural gas flow (orange) and the nitrogen refrigerant loop (blue).

Figure 4 Liquefied Natural Gas facility simulated by the students on HYSYS



The process flow diagram was converted into the HYSYS model shown below in Figure 5. The model is interactive and allows process changes and quick assessment of thermodynamic performance.

Typically, the class of general process simulators has been used widely in the modeling of refining and petrochemical plants. In this project, the students are demonstrating the viability of this software in the assessment of the thermodynamic performance of a utility facility, including a closed nitrogen cycle.

CONCLUSIONS

The concept of the joint project arrangement is consistent with the goals and objectives of the chemical engineering program in that students gain industrial experience while being mentored by faculty and professionals from industry, government, and collaborating universities. The students have the opportunity to publish and present their findings, thus establishing their credentials very early in their careers.

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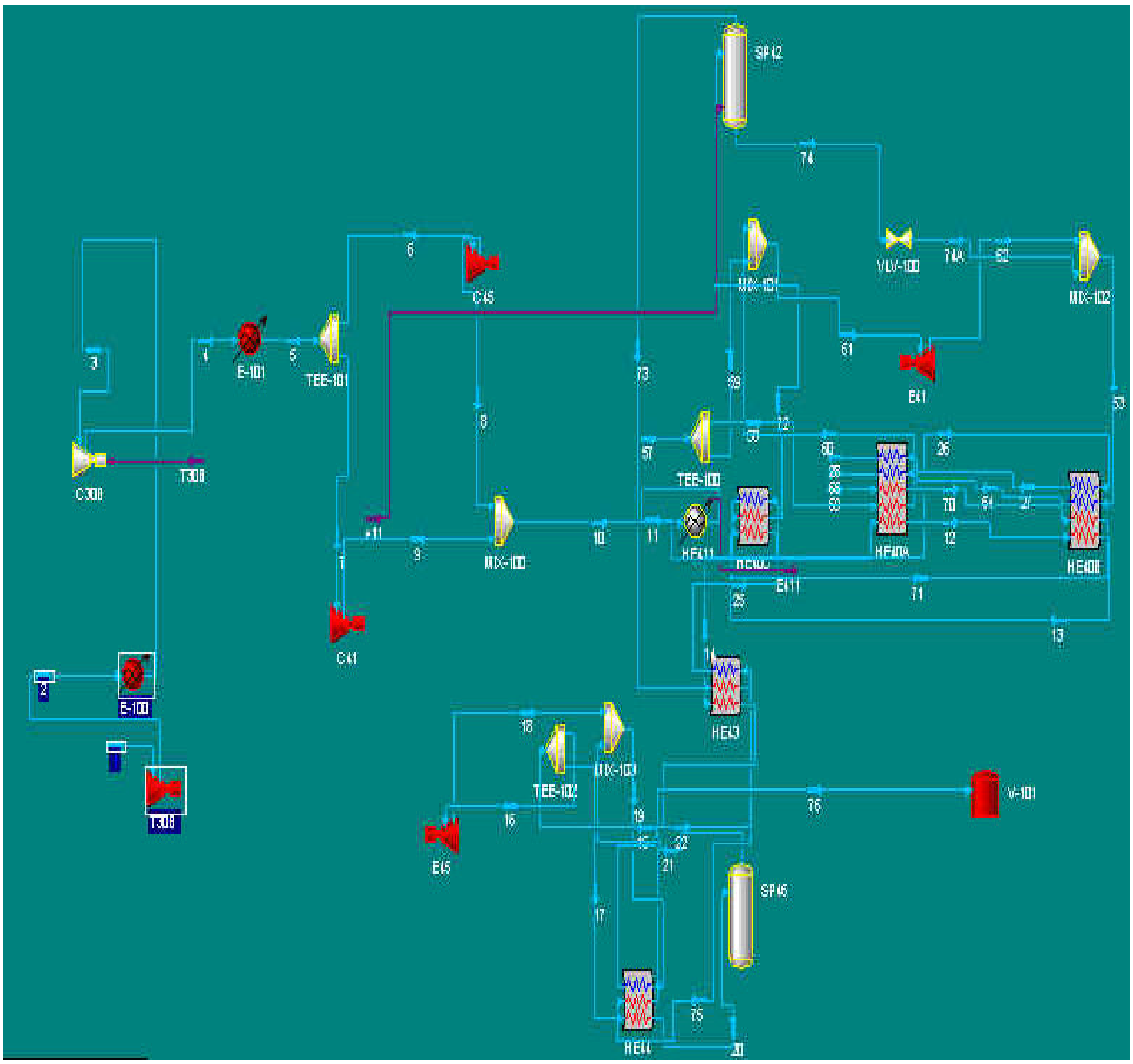

Figure 5 HYSYS Model of the Liquefied Natural Gas Facility

Students translate the process information from PFDs and P & I Ds to HYSYS format. From here the model is interactive and provides material and energy balances, as well as detailed information about each piece of equipment