GLOBALIZATION OF CHE EDUCATION AND RESEARCH:
An NUS-UIUC Model

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In 1998, the National University of Singapore (NUS) and the University of Illinois at Urbana-Champaign (UIUC) initiated a Master of Science (MSc) degree program in chemical engineering that integrates study and work experience in Singapore and the United States. This program is motivated by the increasing importance of the global economy and provides students with opportunities to integrate an international dimension into their education. In addition, the program is designed to provide UIUC and NUS faculty with possibilities for cooperative research and to enhance the visibility of both institutions as leaders in global education and research.

The need for a greater international dimension in a student's education was pointed out to both departments by their corporate partners who emphasized opportunities available at multinational corporations for those with experience in the U.S. and Singapore. In particular, our corporate partners discussed with us their need for students with multicultural, industrial experiences as part of a postgraduate program.

When this program began, participating students received the MSc degree from their home universities, together with a certificate of participation jointly awarded by both institutions. The two universities are now in the process of instituting a joint MSc degree for the program, however. This MSc program provides the impetus for both institutions to extend collaboration to joint research and PhD programs. In this paper, we will present the MSc program with details of the structure, curriculum, and projects completed, as well as the planned extensions of the program.

MSC PROGRAM DURATION AND SCHEDULE

The MSc program is based on pairing Singaporean and U.S. students to ease cultural transitions and to foster collaboration. Students spend nine months in Singapore and nine months in the U.S. During each half of the program, students take advanced courses and participate in an internship. The program began in 1998 with four students (two from each university) and has been well received. The number of participating students has increased each year since that time. From 2000 onward, the target enrollment is ten students (five from each university) for each academic year. Refer to Table 1 for a summary of the program schedule.

U.S. students who apply to UIUC and are admitted into

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TABLE 1
Program Schedule

	July	December	April	September	December
Sing.	Coursework at NUS	Internship Project			
USA			Internship Project	Coursework at UIUC	

Words of Experience

"...Two students (*i.e.* myself and Daniel Zak) from the University of Illinois at Urbana-Champaign have roamed the halls of the Chemical and Environmental Engineering Department here at NUS, as part of a cooperative master's program between the two universities. We have had the opportunity to spend two semesters studying in Singapore. We haven't been alone, though. Two NUS students, Low Mei Yin and Tay Boon Keat, have been with us all along, showing us the ropes and being good friends. When we first arrived, the thing we always commented on was the heat, but who here [Singapore] doesn't know about that? After all this time, we are now faced with the question, 'So what do you think of Singapore?' From our experiences, Singapore has taught us many things.

"Our first semester here at NUS taught us about living in residence halls in Singapore (yes, it is very different from the USA) and about the educational system and structure at NUS. Getting accustomed to living here took quite a while, but by the end of the semester we were more than comfortable with the way of life. We went home (both of us live near Chicago) between semesters, but before going we had been able to travel to Malaysia, Thailand, Indonesia, Hong Kong, China, and Japan. Upon returning from the worst blizzard either of us could ever remember in the USA, it was nice to be back in the tropical climate of Singapore. Our next semester taught us about 'working life,' as we completed an industrial attachment. Dan was attached to TECH Semiconductor with Boon Keat. I was posted to Shell Oil (Pulau Bukom) with Mei Yin. Work life was very different, but just as challenging and rewarding as school. Also, as we had moved off-campus to rented rooms in Clementi, we were exposed to a different way of life in Singapore as part of the local community.

"Now that we are faced with going back to the USA, a tinge of sadness fills us. Of course, our adventures won't be over, because Mei Yin and Boon Keat will be coming back with us. Still, memories of durians (love it or hate it), chicken rice, the Indian stall at the engineering canteen, the Merlion at Sentosa, Raffles Place, Orchard Road, Little India, Clementi Central, the Bugis night markets, the mooncake festival, Chinese New Year, and all the wonderful places we have visited and experiences we have had, will never leave us. It has been an amazing time, and we hope to make it back here someday."

Jonathan Powell

NUS-UIUC Program 1998-99

Figure 1. *Perceptions of the program from a student who participated in it.*

this program join NUS students in Singapore for the first semester of the academic year. The students remain at the university from July to November. Participating students at the host institution are expected to help visiting students with settling-in and orientation (see Figure 1). During this first semester, students take courses and prepare for the internship project.

The internship in Singapore starts in December and lasts through April of the following year. Students then relocate to the United States and work on the second internship project from May until August. Afterward, they spend the fall semester at UIUC, completing the coursework requirement. Thus, students spend equal portions of their time in Singapore and in the United States. Between the coursework semester and the internship period, and also between the two internship periods, there are short breaks of a couple of weeks each. These breaks, as well as the periods before and after the formal program, are appreciated by the students, who often use the time traveling to places of interest.

COURSEWORK AND PROJECT REQUIREMENTS

Students are required to take at least six graduate-level subjects (at least three subjects at each university) and to achieve an average grade of "B" or better at both institutions. In addition, the internship projects must be completed in a satisfactory manner—final reports and oral presentations are required. At NUS, the subjects are to be selected from the list shown in Table 2 (next page). Two of the subjects chosen must have the "CN" prefix, which denotes subjects offered in the department's chemical engineering program. The subjects with the prefix "EV" and "SH" denote subjects offered in the department's environmental engineering program and safety, health, and environmental technology program, respectively. At UIUC, two of the subjects taken must be those approved for graduate credit in chemical engineering. A listing of approved courses is given in Table 3 (next page). While the students are at NUS and UIUC, they are also appointed as teaching assistants or laboratory demonstrators.

The internship period may involve a single project or a number of smaller projects. UIUC and NUS students are usually paired up during the internship period and are assigned to work on the same, or related, projects. The projects are intended to be of a practical nature and relevant to current technology. Examples of industrial projects are given in Table 4. The examples were chosen from projects undertaken in the areas of petroleum refining, microelectronics processing, chemicals/petrochemicals, and pharmaceuticals. The projects are jointly supervised by the company's staff

and staff members from NUS and UIUC, who act as liaison officers. Liaison officers are also responsible for coordinating with the company to ensure suitability of the projects and to grade student reports. As can be seen from Table 4, the projects are a mix of modeling, simulation, and optimization studies on existing plant units, as well as developmental studies on alternative processes.

INDUSTRY PARTICIPATION

The participation of individual companies and foundations through their financial support—and employment of students as interns—is a key factor in the success of this program. The internships also provide close collaboration between industry and academe. The industrial companies supporting the program provide training opportunities in a wide range of areas that are of great interest and importance to chemical engineers. These include process engineering, petroleum/petrochemicals, pharmaceuticals, food, chemicals, and microelectronics processing (see Table 5). The student pairs sponsored by multinational companies, such as Schering-Plough, DuPont, and ExxonMobil, usually work in the companies' U.S. and Singapore plants during their internship. Sponsoring companies without the necessary operations in either country can team up partners to provide complementary internship, *e.g.* Chartered Semi-

TABLE 2
List of Approved Subjects at NUS

CN5010	Mathematical Methods in Chemical & Environmental Eng.
CN5020	Advanced Reaction Engineering
CN5030	Advanced Chemical Engineering Thermodynamics
CN5040	Advanced Transport Phenomena
CN5050	Advanced Separation Processes
CN5111	Optimization of Chemical Processes
CN5114	Advances in Multivariable Controller Design
CN5115	Distillation Dynamics and Control
CN5121	Electrochemical Systems and Methods
CN5131	Colloids and Surfaces
CN5161	Polymer Processing Engineering
CN5191	Project Engineering
CN5193	Instrumental Methods of Analysis
CN5222	Pharmaceuticals and Fine Chemicals
CN5241	Viscoelastic Fluids
CN5242	Two-Phase Flow and Fluidization
CN5251	Membrane Science and Technology
CN5391	Selected Topics in Advanced Chemical Engineering I
CN5392	Selected Topics in Advanced Chemical Engineering II
EV5102	Water Pollution Control Technology
EV5104	Air Pollution Control Technology
EV5202	Quantified Risk Analysis
EV5203	Environmental Impact Assessment and Auditing
SH0004	Fundamentals in Industrial Hygiene
SH0011	Hazard Identification and Evaluation Techniques
SH0014	Safety Engineering
SH0017	Industrial Hazardous Waste Control

TABLE 3
List of Approved Subjects at UIUC

CHE465	Chemical Engineering Seminar
CHE466	Applied Mathematics in Chemical Engineering
CHE467	Chemical Kinetics and Catalysis
CHE469	Special Topics in Chemical Engineering
CHE485	Non-Newtonian Fluid Mechanics and Molecular Rheology
CHE486	Surface Chemistry
CHE487	Fluid Dynamics
CHE488	Advanced Topics in Heat and Mass Transfer
CHE496	Individual Study
CHE497	Special Problems

TABLE 4
Examples of Internship Projects

Petroleum Refining	• Modeling and optimization of lube hydrocracking and dewaxing units. • Simulation of hydrocracking units and reactor sections for maximizing naphtha production.
Chemicals/Petrochemicals	• Simulation models of NO_x absorber to estimate temperature profile, release rate of NO_x during disturbance, and vent area required to prevent over-pressurization of tanks. • Developmental work on azeotropic distillation of Promoter X using a packed-bed distillation column.
Pharmaceuticals	• Pilot scale studies on liquid-liquid extraction as an alternative to the double precipitation process for production of Z. • Feasibility studies of the recovery of vaporized liquid N_2 and the integration of N_2 vaporization with VOC condenser systems.
Microelectronics Processing	• Optimization and cost-saving options for ultrapure water facilities. • Application of phase-shift masking for sub-0.16μm contact hole imaging.

conductor Manufacturing in Singapore and Applied Materials in the U.S.

Some companies may require the Singapore students to return to work for a specified period of time (two years) in return for sponsoring student participation in the projects. In practice, however, many of the companies do not require commitments, and the employment of graduates by the companies is mutually agreed upon.

Through financial incentives, staff members are encouraged to participate by visiting the companies in order to discuss and formulate the projects and to provide feedback on the project work. During these visits, staff members establish contacts that eventually may provide research connections. Companies may require participating students and staff members to sign a deed of confidentiality.

CHALLENGES AND FUTURE PLANS

The MSc program is now in its fourth year and has been positively received by students, sponsoring companies, and both institutions. Survey data and informal feedback from participating companies indicate that the program is of benefit to all stakeholders. Students from both countries learn a great deal about living and working in different cultures and applying skills learned in the classroom to real plant problems. The corporate partners appreciate contact with, and the projects carried out by, a group of highly motivated and unusually adventurous students. Each institution, however, also recognizes the amount of effort required to coordinate the academic activities and the planning and management of projects with industrial sponsors. A staff member has been appointed by each department to serve as a coordinator for the program and to liaise with the students, university administrators, and industrial sponsors.

The coordinators also assist students in the procurement of travel documents and housing arrangements. While the students are in Singapore or at UIUC, they are eligible for student housing. During the internship in various parts of the U.S., however, they have to make their own housing arrangements, although some companies provide assistance in this respect. The "buddy system," whereby participating students from the host university play an active role in helping visiting students settle in, alleviates some of the difficulties.

Both institutions are now in the final stages of working toward awarding a joint MSc degree for graduates of this program. The success of the program sets the stage for further collaboration in chemical engineering between the two institutions. In January of 2001, the departments jointly organized an NUS-UIUC Joint Symposium on Globalization of Chemical Engineering Research where intensive discussions were conducted in an effort to design a joint PhD program. There is already collaborative research going on between chemical engineering faculty members at NUS and UIUC. A joint PhD program will, however, formalize and further enhance this collaboration, providing visibility for the quality research that can be done with the skills, resources, and ideas of NUS and UIUC faculty members in a combined effort of this type.

This program is being implemented with a shared commitment to excellence in education and with research based on collaborative efforts—where the interests, capabilities, and resources of each institution combine to offer unique and advantageous opportunities. ❐

TABLE 5
List of Participating Companies in NUS-UIUC MSc Program

Company	Years Participated
Chartered Semiconductor Man.	2000-01, 2001-02
DuPont	1999-00, 2000-01
Applied Materials	2001-02
Mobil/ExxonMobil	1999-00, 2000-01, 2001-02
Glaxo-SmithKline	2001-02
Kraft	1998-99
TECH Semiconductor	1998-99
Shell	1998-99, 2001-02
Schering-Plough	1999-00, 2000-01, 2001-02
Honeywell	2001-02

ChE books received

Turbulence Structure Vortex Dynamics, edited by J.C.R. Hunt and J.C. Vassilicos; Cambridge University Press, 40 West 20th Street, New York, NY 10011-4211; 306 pages, $80 (2001)

Foundations of Spectroscopy, by Simon Duckett and Bruce Gilbert; Oxford University Press, 198 Madison Avenue, New York, NY 10016-4314; 90 pages, $12.95 (2000)

An Introduction to Magnetohydrodynamics, by P.A. Davidson; Cambridge University Press, 40 West 20th Street, New York, NY 10011-4211; 431 pages (2001)

Organotin Chemistry, by Alwyn G. Davies; VCH Publishers, Ic., 337 7th Avenue, New York, NY 10001; 327 pages (1997)

Stereochemistry of Coordination Compounds, by Alexander von Zelewsky; John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158-0012; 254 pages (1996)

Hydrocarbon Resins, by R. Mildenberg, M. Zander, G. Collin; John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158-0012; 179 pages $140 (1997)

An Introduction to Turbulent Flow, by Jean Mathieu and Julian Scott; Cambridge University Press, 40 West 20th Street, New York, NY 10011-4211; 374 pages, $90.00 (hardback), $39.95 (paperback); (2000)

Computational Analysis of Biochemical Systems, by Eberhard O. Voit; Cambridge University Press, 40 West 20th Street, New York, NY 10011-4211; 531 pages, $130 (hardback), $49.95 (paperback) (2000)