This column provides examples of cases in which students have gained knowledge, insight, and experience in the practice of chemical engineering while in an industrial setting. Summer internships and co-op assignments typify such experiences; however, reports of more unusual cases are also welcome. Description of the analytical tools used and the skills developed during the project should be emphasized. These examples should stimulate innovative approaches to bring real world tools and experiences back to campus for integration into the curriculum. Please submit manuscripts to Professor W. J. Koros, Chemical Engineering Department, University of Texas, Austin, Texas 78712.

INTERNATIONALIZING PRACTICAL ChE EDUCATION

The M.I.T. Practice School in Japan

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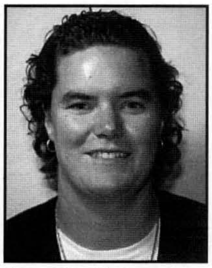
Graduates entering today's increasingly global chemical industry require not only strong technical skills, but also the ability to apply those skills successfully to solve practical problems along with an appreciation of the diverse features of industry around the world. Although classroom education is not the optimal way to develop all of these skills, it can be well complemented by practical experience gained outside the traditional university environment. Many internship and cooperative education programs exist to provide students with industrial experience during their undergraduate and graduate engineering courses, but exposure to the international world of industry and business is generally not available to students until after they commence graduate employment.

Recognizing the importance of developing an understanding of international industrial practices in its graduates, the David H. Koch School of Chemical Engineering Practice (the "Practice School") opened a new chapter in its history two years ago by initiating its inaugural overseas station. The Practice School, administered by the Department of Chemical Engineering at M.I.T., has educated chemical engineers in both the science of chemical engineering and the art of chemical engineering practice since 1916, with only



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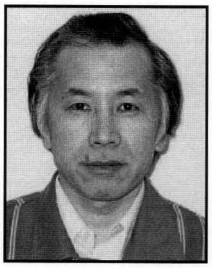
***Angelo W. Kandas** was the Assistant Director of the Mitsubishi Chemical Corporation Station in the summer of 1997. A Practice School graduate, he holds a PhD in chemical engineering from M.I.T., where his thesis was on "The Evolution of Carbon Structure During Oxidation." He is now a Senior Process Engineer at Intel Corporation, conducting research on oxide etching. (Photo not available.)*



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brief interruptions during the two World Wars.[1] The Mitsubishi Chemical Corporation (M.C.C.) Mizushima Plant in Kurashiki, Japan, was selected as the site of the program's first industrial station outside the U.S., and it hosted seven M.I.T. student for two months in the summer of 1997.

The key issue in establishing an overseas Practice School station was to ensure that the quality of the educational experiences gained by the students was not diminished by the cultural or language differences, but rather was enhanced by exposure to these differences. With careful preparation by M.I.T. and M.C.C. staff and strong support of the students' endeavors at the station, the station operated very successfully. This article describes how the station was established and the benefits and difficulties of the addition of an overseas station to the Practice School program.

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THE PRACTICE SCHOOL

Students enrolled in the Practice School undertake two semesters of graduate-level courses in chemical engineering at M.I.T., followed by three to four months of intensive project work at two remote industrial stations. Successful completion of these tasks leads to graduation with a Master of Science in Chemical Engineering Practice. The industrial project work takes the place of the thesis component of some other Masters programs, and a high standard of achievement is therefore expected. Industrial stations have operated at a number of different company sites—recently Dow Chemical (Freeport, Texas), Merck Pharmaceutical (West Point, Pennsylvania), GE Plastics (Mt. Vernon, Indiana), and Cargill (Minnespolis, Minnesota) have hosted Practice School groups.

The students work in groups of two or three, and each group works on one project for four weeks. In this short time, the students must assimilate the problem they are assigned, develop a method of approach, carry out the project work, and present both written and oral reports. Their efforts are supervised and assessed by the Station Director and the Assistant Station Director, both M.I.T. staff members who reside at the station full-time. The program is structured with regular meetings and reporting deadlines to ensure the students' efforts are appropriately focused and that good communication is maintained between the students, the project sponsors, and the Station Directors for the duration of the project. Details of the program structure have been described previously.[2]

One student from each project group is designated as the group leader and is responsible for management of the project and effective communication throughout the course of the project. All students contribute to oral and written reports each month, and the groups and group leaders are changed for each new project. Company engineers act as project sponsors, providing problems for the students to work on and acting as consultants to the student groups. The M.I.T. staff and students are bound by confidentiality agreements with the host companies, so they are granted broad access to in-house data and know-how.

The projects must meet a number of criteria in order to be suitable for the Practice School: they must be of educational value to the students; they must require in-depth technical work, original thinking, initiative, and engineering judgment in their execution; and they must be of high priority to the host company. Furthermore, the personnel, plant, and other resources necessary for the project to progress must all be available during the four-week period that the project is assigned to the students. Routine delays such as those required to purchase a new equipment item cannot be accommodated after projects commence due to their short duration. It has been estimated by plant project engineers at previous stations that, as a result of these students' single-project focus, diligence, and aptitude, a typical pair of Practice School students can achieve in one month of work on a project what a company engineer might require four to six months to complete.

THE M.C.C. STATION

The opportunity to experience from within the day-to-day operations of M.C.C.'s Mizushima Plant was understandably inspiring to the students selected to attend this station. M.C.C. is the largest chemical manufacturer in Japan, and the Mizushima Plant is one of their major operations, with around 1800 employees and $1.1 billion worth of product shipped annually (1995 data). The plant is located in a petrochemical industry complex with port facilities on the Seto Inland Sea, and it manufactures a broad range of petrochemicals and memory media for computers. In addition to the manufacturing facilities, the Mizushima Plant has the Development and Engineering Research Center (DERC), which conducts a broad range of process development, modeling, and optimization projects to develop leading-edge technology for the future operations of M.C.C. This center was the host to the Practice School, and projects were offered by several specialist groups within the center, led by M.C.C. engineers with strong technical and English language skills.

Seven students were selected to attend the station based on their expressed interest to work in Japan. They spent one month at the Dow Corning station (Midland, Michigan) prior to arriving at M.C.C., where they worked for two months. It was important for the students to gain experience in a U.S. Practice School station before tackling the program in Japan, to familiarize them with the program expectations and to give them confidence in their ability to meet these expectations in a more familiar environment. The students all held undergraduate engineering degrees and had completed the graduate course requirements of the Practice School program at Cambridge. Only one of the selected students spoke Japanese, so the others also enrolled in an introductory Japanese course at the local Adult Education Center, and all attended two half-day workshops run by the M.I.T. Japan Program to prepare them for living and working in Japan. Visas and work permits were arranged for the students, the only difficulty being the added documentation and guarantees of support required for some non-U.S. students.

The students arrived in Japan several days before commencing work, enabling them to recover from jet lag and acclimatizing them to living in Japan. Apartments were provided in the M.C.C. housing complex alongside Japanese employees and their families. The costs for housing, as well as for travel to and from Japan, were covered by M.C.C. Initial challenges facing the students included learning to manage shopping, banking,

Case Study 1. Optimization of Polymerization Catalyst Properties

A polymerization catalyst is synthesized in a batch process by precipitation from a reaction mixture following a complex sequence of reagent additions and temperature adjustments. Increased demand for certain polymer product grades necessitated improved control of the catalyst particle size distribution (PSD) in order to maximize the production capacity of the polymerization train.

The students initially performed a statistical analysis on the existing laboratory and pilot-plant data for the catalyst synthesis under a range of conditions. Using techniques learned in a Practice School course on statistical analysis and experimental design, they were able to determine which variables have a dominant effect on the catalyst PSD, but did not have sufficient data to quantify these effects. So they used the statistical analysis software SAS to design an experimental program to investigate the effects of the dominant parameters. Appropriate experimental design was important to maximize the information obtained from the limited number of laboratory experiments possible in the short time frame, as each experiment took about fourteen hours to complete.

The students then conducted the experiments in collaboration with their project sponsors. They planned their time carefully so that two students were in the laboratory at all times during an experiment; the third group member was also in the laboratory for the more labor-intensive parts of the experiments, and in the office the rest of the time. This was necessary to enable the group to read sufficient background material, to develop data-analysis techniques, and to meet the weekly reporting deadlines. They arranged a roster to share the duties most efficiently.

On-line measurements of the PSD using a laser-reflectance probe provided extra information from the students' experiments, enabling them to identify further important variables that had not been previously studied. It also enabled them to postulate the mechanisms governing the PSD, providing key insights into the physics of the process. The experimental results were added to the existing data set and analyzed using SAS to determine the dependence of the catalyst PSD on the manipulated variables. The results confirmed the trends previously observed in pilot-plant trials, but also identified some important variables that were previously not considered significant. The students recommended changes to the catalyst synthesis procedure based on their results, and they were implemented with distinct improvements in the catalyst properties.

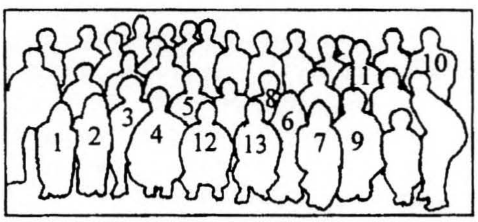
Case Study 2. Process Flowsheet Development for a Byproduct Purification

A process was being developed to implement a new catalyst in a synthesis process. The new catalyst produces the desired product (A) plus a significant quantity of a valuable byproduct (B), which needs to be purified in order to be marketable. The byproduct can be separated from the major product stream relatively easily, but is contaminated with several other compounds, including an undesirable byproduct (C). Byproducts B and C are difficult to separate because they differ only in their degree of saturation. The clients wanted to determine the optimum plant configuration and operating conditions to purify byproduct B.

The students studied previously conducted experiments and process simulations on azeotropic distillation as a potential separation method for B and C and found that the physical property data initially used in the simulations were inadequate, leading to gross overestimation of the separation efficiencies. They used refined physical property estimates to conduct Aspen Plus simulations, obtaining results matching experimental data, which showed this technique to be infeasible.

They conducted an in-depth literature review of other possible separation techniques and discovered several possibilities that had not yet been considered. They investigated the feasibility of a range of techniques, with the assistance of information from the literature, Aspen Plus simulations, and consultations with experts at M.C.C. One new technique involving solvent extraction with a pH swing was found to be favorable. As a result of this discovery, measurements of the distribution coefficients of B and C in an appropriate extractant were rapidly commissioned to provide the necessary data for the students to simulate this process. They used these data in Aspen Plus simulations to design and optimize the flowsheet for the byproduct purification section of the plant. The new process required many fewer unit operations than previous proposals to meet the product specifications and also simultaneously removed other contaminants from byproduct B.

The students conducted preliminary economic analyses on the proposals investigated and made recommendations of further refinements needed in the simulations of the most favorable proposal. As a result of the students' findings, the clients switched their attention from the unfavorable azeotropic distillation initially proposed to a simpler and more cost-effective extraction process.



After their final oral project reports, the M.I.T. students (Celia Huey, 1; Karen Zee, 2; Justin Zhuang, 3; Alejandro Cano-Ruiz, 4; Thomas Gubiotti, 5; Susan Dusenbery, 6; Tanya Moy, 7) with the Practice School Directors (Alan Hatton, 8; Andrea O'Connor, 9; Angelo Kandas, 10) and M.C.C. staff members (including Plant General Manager, Mitsuyoshi Mitsuoka, 11; D.E.R.C. Director, Hiroyuki Kobayashi, 12; D.E.R.C. Deputy Director, Yukikazu Natori, 14).

and traveling around the local area where English was rarely spoken. Bus transport, provided by M.C.C. to all employees, was used to travel to the plant on weekdays, and bicycles were used on the weekends.

During the first week in Japan, prior to the start of the station operations, the students were taken on a three-day excursion to Kyoto and Nara by bullet train. This trip served as an excellent way for the students and directors to get to know each other, and to learn a little about the culture and history of Japan. Escorted by a member of the Personnel Section of M.C.C., the students learned about some of the significant sites in these two old capitals of Japan and gained confidence in the day-to-day living skills they would need throughout their stay in Japan.

The station facilities provided by M.C.C. included desks in a large, open-plan office with other M.C.C. employees, and company uniforms (a symbol of belonging to the organization). The students worked within a firmer daily schedule than at U.S. stations, as they used the company bus for commuting between the plant and the apartment complex, and required an English-speaking staff member to be on site with them when working on weekends, in case of emergencies.

At this station, the students met regularly with their project teams, comprising several M.C.C. engineers and scientists for each project. They also benefited from interaction with DERC senior engineers and technical specialists in areas such as modeling and process optimization. M.C.C. staff members from other sections, and even other sites, attended the students' oral presentations, and the students had an opportunity to make poster presentations in an annual M.C.C. poster session, further broadening their exposure to company personnel. It was not generally possible, however, to establish meaningful interactions between the students and operators because of language barriers. Thus, all plant information was gained via the project sponsors, and instructions for experiments or plant trials run by the students had to be communicated to the operators via the sponsors. While this is a drawback of the language barrier, it is not atypical for consultants working in foreign countries, and it was good experience for the students, giving them an appreciation of the difficulties this can generate.

Working at a Practice School station is often a time of stress for students, and being in a foreign country can exacerbate this. Hence, a special effort was made to ensure that some time for relaxation away from the workplace was set aside each week. In order to avoid any feelings of isolation, as well as to make the most of the opportunities to experience Japanese life and culture, activities or excursions were

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organized for the students each weekend. A number of M.C.C. staff members often joined these activities, providing further opportunities for cultural interactions. Examples include a day trip to Hiroshima to tour the Peace Park and A-Bomb Museum, plus Miyajima Island, location of one of the "three best views in Japan"; trips to the beach; playing in an M.C.C. badminton tournament; and joining the traditional Bon Dance Festival.

PROJECT REVIEWS

The projects selected at the inaugural M.C.C. station were all ambitious and important to developments underway at the time. On the first day the students attended the plant, they were introduced to M.C.C. and the Mizushima Plant, including the personnel with whom they would interact, and to company regulations. They also received training in plant safety. Each group was then presented with a several-page problem statement, prepared by the Station Directors, describing the background of their allocated project. The specific project aims were stated and a suggested method of approach was provided. There were elements in each project, however, that were quite open-ended and required the students to develop their own plan of attack in consultation with their sponsors and the Station Directors.

Practice School projects are generally diverse and may include optimization of an operating plant, research, or design, or a combination of these. Two examples of projects undertaken and the work executed by the students are highlighted in the sidebar box, within the bounds of company confidentiality. One student observed that the "projects were very technical in nature, and our sponsors have given us a great deal of trust in executing them. I feel that we actually made a contributiony." Another student noted that "we were given real problems and were expected to give real solutions."

PROS AND CONS OF GOING INTERNATIONAL

The benefits of the experience of successfully completing a semester at Practice School stations were as strong as ever for the students who attended the M.C.C. station. The skills they gained included: problem solving in an industrial context; project planning and management under tight deadlines; application of integrated chemical engineering skills and engineering judgment; strength in written and oral communication; and enhanced teamwork and leadership abilities.

In addition, they gained an intangible but important insight into the operation of a major Japanese corporation from within. For both the students and the M.C.C. staff with whom they worked, the opportunity to form international networks and build understanding of their differences and similarities in culture, language, and business practices will be extremely valuable in their future careers.

There were some disadvantages that we were not able to overcome. In particular, the language barrier limited the M.C.C. staff members with whom the students could communicate. The project sponsors were very capable and enthusiastic to communicate in English, but many of the operators and technical staff were not able to interact with the students. This closed off a potential source of process information and kept the students from attempting the sometimes-difficult task of forging good working relationships with operators.

Factors such as this make the combination of experience at one U.S. station and one overseas station ideal. While these problems can be alleviated to some extent by considering language skills during the student selection process, it is unlikely that all students assigned to an international station will have a working knowledge of the language spoken at that facility. We will continue to provide such students with basic instruction in the language and culture of the host country.

CONCLUSION

The Practice School experience at M.C.C. in Japan demonstrated that operating an international industrial training station as part of a practical engineering education program can be highly successful. In spite of initial concerns over language and cultural barriers, the students' performance in the overseas environment was of the high standard expected in the Practice School program, and they also benefited greatly from exposure to and interactions within a major Japanese company. Despite the high intensity of the program and the stress of living in a new environment, the first students at the M.C.C. Practice School station all recognized the advantages of their overseas experience and were pleased to have had the double opportunity of Practice School training plus experience in industry overseas.

The Practice School intends to maintain a presence overseas; last year international industrial stations operated at Rhone Poulenc (France), Bayer (Germany), and again at M.C.C.'s Mizushima Plant. While it is important that the international stations never replace the U.S. stations completely, they make an excellent complement to students' experiences in the U.S.

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