Mike Doherty

of the

University of California, Santa Barbara

MARY E. HOWE-GRANT

Chemical Engineering Professor Michael Doherty says, "The great thing about being a scholar is that by teaching students you really get to learn the material yourself! Research is incredibly important, but a scholar is different from a researcher—scholars distill a coherent story about a subject out of their own research, the literature, and their personal experience. It's in teaching and writing textbooks that the material is really mastered—and passed along."

Mike Doherty still loves teaching and the opportunities for interaction with students that it brings, although teaching at the university level gains people's respect but rarely serves as a means to professional advancement. Mike likens teaching to being an actor in a play, where an enormous amount of time goes into the preparation. He's taught dozens of design courses to seniors and industrial practitioners, yet it's new and challenging every time! And when he's teaching, it consumes him.

Although Mike can teach many courses in the chemical engineering curriculum, there's only one he feels he can teach better than most anyone else—the senior design course. Why? Because while not many people know the coherent body of knowledge that goes into creating a process flow sheet from scratch, Mike learned "the touch" at U Mass from Jim Douglas, one of the greatest in the field. Douglas, during much of the latter half of his career, struggled successfully to develop a cohesive framework for teaching design.

Many people in chemical engineering believed that design can only be learned by experience, and that is certainly how the course has traditionally been presented. As a consequence, design projects usually left the students feeling deflated right at the time they were graduating and going out into the world. Douglas, convinced there was a better way, developed a methodology, and the publication of his book, *Conceptual Design of Chemical Processes,* in 1988, revolutionized the approach to this subject. Design can now be taught in a systematic way.

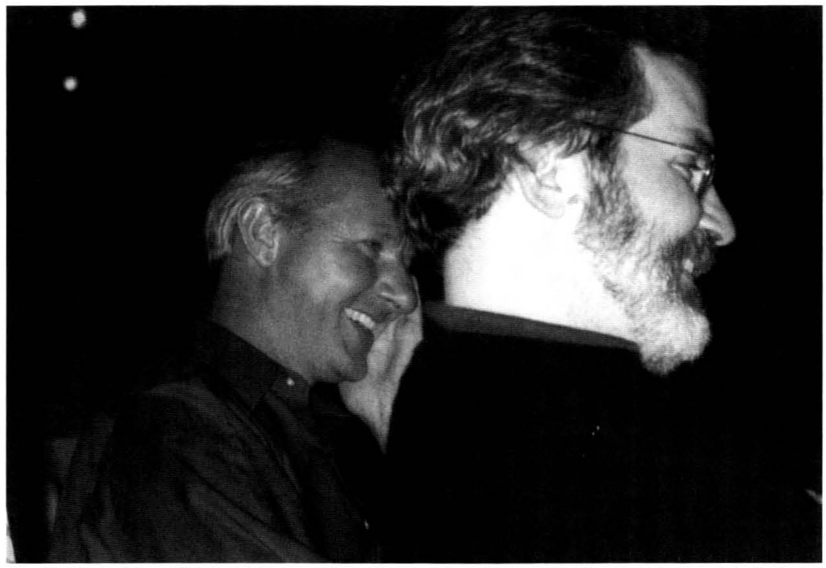
On a bet that he wouldn't dare do it, Mike taught the first class in his junior fluid mechanics course in Fall 1979 dressed as a Redcoat.

Rather than thinking serially about design, *i.e.* developing each section of a plant in excruciating detail and then throwing the developed sections together at the end, Douglas showed that it's possible to take a hierarchical approach to the design process. Moreover, the result of using this methodology is a much more satisfactory outcome. The procedure a chemical engineer goes through can be compared to that of an artist painting a picture, where one starts with the big concept, producing a series of sketches later to develop the details. For a chemical process that means starting only with what comes in and what goes out. Moving downward into the complexities, one layer at a time, decisions are made that influence what comes next. Separations systems, Mike's forte, is, of course, one of the big blocks.

Mike has been teaching the senior design course since the mid-1980s. The current version, a two-quarter sequence that has an annual average enrollment of around 30 students, is nontraditional and, says Mike, "... fun to teach. It doesn't focus on synthesis or analysis of processes alone—it also focuses on *decision-making*. Plus, undergraduates are the last group of people who will ever believe you. Seniors are the last chance to make an impression."

What students get out of [Mike's] course they carry with them for life, whether they remain engineers or choose another career path. They learn how to go about making decisions in a logical way, how to look at a large problem and go about breaking it down to make the big decisions first.

The course shows students that they can actually invent something from scratch. For the students it is truly a capstone experience as they get to decide almost everything about the process. Using the hierarchical methodology, they work in teams of two (any more and some team members become just passengers), making the simple decisions first. They can't really fail in this initial step in the hierarchy of decisions. Rather, they explore different sets of alternatives. Then, by disentangling the information between the layers, they learn first-hand about the trade-offs required in process design, *e.g.*, that the benefits to production in using extra materials are offset by the increased demand placed upon the separations system. What students get out of this course they carry with them for life, whether they remain engineers or choose another career path. They learn how to go about making decisions in a logical way, how to look at a large problem and go about breaking it down to make the big decisions first. Then, once a set of decisions is made, they are taught how to evaluate those decisions.



Reseachers like to have fun. Mike (left) and Mike Malone (right).

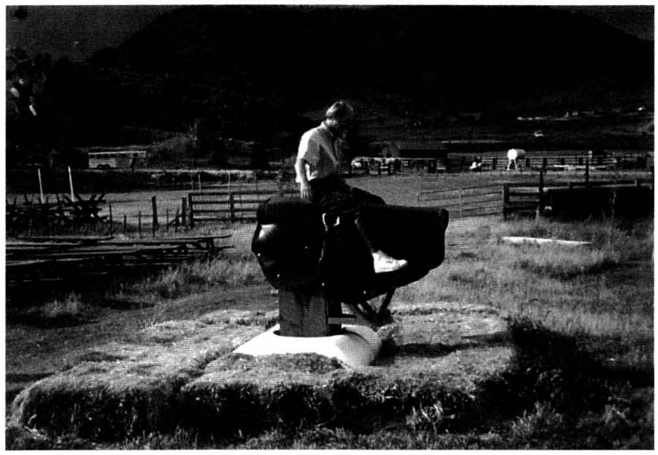
In the business world, chemical engineers must incorporate more than just good engineering in their designs. Monty Alger, a chemical engineer at GE Plastics in Pittsfield, MA, says, "The role of the engineer in industry is to make, evaluate, and justify technical decisions in support of business." So, in the first two-and-one-half weeks of the senior design course's second term, the focus turns to a business challenge problem, originally developed by Alger. To be successful, the students have to understand the chemistry of the process—plus, they need to be able to cut manufacturing costs through good process engineering and to expand the business through strategic investments in product development and marketing. Mike tells his students, "You are not a chemist and you are not a business major, but you need to be able to take what a chemist produces and turn it into a viable business. You cannot do this with engineering alone; you have to be able to make things happen that are a surprise to both sides. If not, then you won't be needed as engineers because the company can do it without you."

The business focus arose after many graduates from good programs, confident they could design anything and thinking they had all the answers, were confronted with business decisions in the real world and would, according to Alger, seem to rely on magic, not logic, to solve the problem. Mike wasn't so sure that his students would be so clueless. So Alger approached Mike with a proposal in the Fall of 1997: "I'm going to form a realistic chemical process business problem and give it to your students at the end of your design course and see how they do." Alger worked nights and weekends and finally rolled out a business problem game complete with an extensive database for providing end-of-year income statements for the many technical-business decisions made by the players. The students were to prepare and submit a budget statement (with appropriate technical justification for process modifications) that would salvage a loss-making business and turn it around to profitability within three budget cycles. The database ensured that the paths and results depended on the decisions that were made. Sure enough—instead of approaching the problem with the logical methods they had learned, the students started relying on magic.

Mike was initially devastated. He'd gone out of his way to teach students to be systematic. Then, when placed in a real-world situation, they had indeed failed to attack the problem logically. There was only one solution: incorporate more real-life business situations into the course.

Mike absolutely believes in the design process he teaches. He's involved in an off-campus company in which the conceptual engineering team is able to make technical/economic decisions so rapidly that they influence the research directions and goals of the discovery chemists in real time. "We work faster and better than anybody else in the business," he says, " because our chemists can focus their research on solving the problems with the greatest economic and engineering impact."

A chemical engineer can design a chemical system to work in a way chemists might not think about. Using the hierarchical methodology developed by Douglas allows the engineer to work quickly. Generally the decisions made at the very beginning, designated "Level I," are the most important. And, in order to make those decisions logically, it is absolutely essential that the engineer understand the chemistry of the process. Otherwise, the process itself will never be understood. To be successful, it is also necessary to understand the business side of the equation.



As co-chair of FOCAPD-94 in Snowmass, Colorado, Mike gets first crack at the mechanical bull.

Real-life challenges tend to be bigger than academic ones. Usually, a discovery chemist making one gram (or smaller) samples is going about the process all wrong in terms of commercial production. The chemist focuses on making high yield of material, not on the more than 95% selectively necessary to the commercial process. But the company can't afford tons of waste, so the engineer needs to be able to get back to the discovery chemist quickly to carry out experiments under other sets of conditions, as well as to link directly to the business community.

Just as in the design course, Mike has come to realize that engineering is more than science. "I'm beginning to preach—just like Jim!" Mike exclaims wryly.

Ask Mike Doherty about his friends and he'll tell you they're a bit unconventional. It all started when he went to Imperial College, University of London, in the Fall of 1970. When Mike entered Imperial, he stepped into a whole new world. Excited, yet strangely at home, he never looked back. The early '70s was an amazing time, especially in London—*the* place to be! There were people who had green or brilliant red or bright yellow hair right next to short-haired, well-coifed men in pinstripes. And at Imperial, located in the center of South Kensington (between Knightsbridge and Chelsea), the dorms circle the campus and the Royal College of Art is just across the street. Mike loved every bit of it.

Born in 1951 and educated through high school in Manchester (England), Mike had studied hard, done well, and knew he was interested in studying science. All the better students at his high school who continued their studies in science went on to the University of Manchester, but Mike was determined to escape his provincial confines. London was a giant step away from life as he knew it, and he embraced it.

Mike's first year at Imperial was, understandably, spent taking in both the social and academic scene and developing a sense of himself. He was immediately exposed to other cultures and socio-economic classes—his first-year roommate was the son of the British High Commissioner to Fiji. Mike often ate at the Royal College of Art and made friends there. His third-year roommate was an artist.

Mike also explored academically. He'd entered Imperial as an engineering student, but in his second year he decided he wanted to try medicine. His Department Chair talked him out of it, however. Then in his third year, he considered switching again—to physics—but again the Department Chair dissuaded him. These yearnings vanished when he started work on his required independent research project and fell in love with thermodynamics. Mike, who had never doubted his ability to do the work, was now excited about it. He was more than happy to work long and arduous hours and to devote himself to his project.

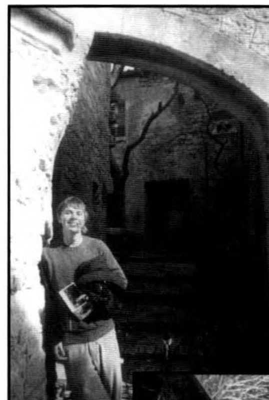
Mike and his partner were under the supervision of two advisors: John Rowlinson, the great molecular thermodynamicist, served as the strategist, and Graham Saville was the tactician. The project consisted of computing phase equilibria from the newly formulated Bender Equation of State, using twenty constants to represent PVT data. They derived expressions for the chemical potential and then solved for equal potential across phases. The brand new mainframe computer at the students' disposal (a CDC 6600) required that they program it in machine language—with a three-feet-long deck of computer cards that required overnight runs.

Mike was certain he had found his calling and Rowlinson did his part to ensure Mike's success. In an unusual step at that time, Rowlinson took Mike, an undergraduate, to a thermodynamics research conference, paid his way, and introduced him to many of the participants. As a result, arrangements were made for Mike to pursue his doctoral studies in chemical engineering at Rice University under the supervision of Tom Leland, a distinguished statistical mechanician.

In mid-1973 Mike Doherty, Imperial College degree in hand

Family Album . . .

◀ ***Mike (left) and his long-time friend, Dave Pinardi, jazz musician extraordinaire, drove the entire length of Route 66 on their way from Massachusetts to Santa Barbara (2000)***



▲ ***Mike's son Max on a three-month sojourn to a French lycee during his junior year in high school.***

▲ ***Sarah, Peggy, and Max enjoy breakfast on Cape Ann, MA.***

Mike and Peggy prepare to take a sunset cruise in December, 2002. ▼

◀ ***Peggy outside their home in Mass.***

and his eye on his academic future, set out for the U.S. His plan was to stop off in New York to see a woman, a Barnard College student whom he'd met the previous summer, then to continue on for a vacation in California and Mexico before reporting in at Rice in August. But, in the words of Robert Burns, "The best laid schemes o' mice an' men, gang aft a-gley." Mike, whom no one ever accused of being satisfied with the status quo, never made it beyond New York city on that trip.

By mid-August, he was still in this woman's apartment in Greenwich Village and was working as a cocktail waiter in a night club. Although a bit uncertain about his future, he'd decided not to go to Rice. Then, as fate would have it, Mike's father called from Manchester to report that Trinity College, Cambridge, had been pestering the family, asking whether Mike would be coming in the fall to pursue graduate studies—and Cambridge didn't start up until early October.

Mike sent a telegraph, "Hold place, am coming," left NYC on October 1st, and went straight to Cambridge. The first person Mike happened to see when he arrived at Cambridge was a fellow who had been a third-year undergraduate student at Imperial College when Mike was in his first year there. John Perkins was incredibly smart, a whiz kid, who had stayed on at Imperial for his PhD in the field of control, completing it in two-years. The encounter was a surprised to each of them.

Cambridge University was definitely where Mike wanted to be, but he was disappointed that no one in the chemical engineering department was doing statistical mechanics. So he wandered around wondering what he might do until Christmas, thinking there would be nothing for him at Cambridge unless he was willing to work on fluidized beds. Then it dawned on him! To stay he needed to develop a project of his own!

Mike had just read a very descriptive book on extractive distillation that contained enough thermodynamics, he thought, to use as a starting point for developing a mathematical model. Moreover, he felt the model should be generic and global enough to apply to other types of azeotropic distillations. So Mike went to John Perkins, whose work was highly mathematical, and said, "You need students and I need an advisor. Let's develop a theory of azeotropic distillation that can be applied globally for all mixtures." And John came to Mike's rescue, saying, "I will be happy to be your advisor but I'm not going to be your foreman."

So Mike Doherty became John Perkins' first student and the only one working on separations system design. It took longer than Mike expected to formulate a useful theory of extractive and azeotropic distillation, but eventually he found the right mathematical framework, using geometric methods from nonlinear differential equations. Their first paper on the mathematical theory of residue curve maps for azeotropic distillation has been cited hundreds of times. Once Mike unraveled the thread of extractive distillation, he discovered it was only the tip of the iceberg. Indeed, the main topics of his highly mathematical dissertation subsequently led to topics for about a dozen PhD students of his own. Years later this led to "the best collaboration I could imagine" with his colleague Mike Malone. During a twenty-year period, their joint group produced about twenty graduates, dozens of papers (two of which won Best Paper of the Year awards in the journal *Computers and Chemical Engineering*, and one of which was published in the journal *Nature*), and a recent textbook, *Conceptual Design of Distillation Systems*, published by McGraw-Hill in 2001.

Perkins proved to be a great advisor. Thinking back, Mike says, "John was young, very smart, full of confidence, willing to explore unconventional ideas, and then finish the day over a pint. John can be pretty intimidating and many people are unable to get close to him, but I was lucky to get to know him while we were both young. I learned a great deal about how to advise students from him. He taught me some great lessons."

Mike's personal life also stabilized somewhat during his years at Trinity. In 1974, his second year, Peggy, his friend from New York, came to England to be with him. In looking for work, she immediately found herself in a bureaucratic Catch 22. Because she was a foreigner, she needed a work permit to get a job...but a job was a requirement to obtain a work permit. After several months and down to their last few pennies, they were getting desperate, so Mike called his father to announce, "We're getting married tomorrow." Not only did married students make more money and have better housing, Peggy, as the wife of a British citizen, would be able to get a work permit.

Mike's father responded, "I'll send you 100 pounds to tide you over. Come home to Manchester and get married with all the family around. Your mother and sisters will make the wedding dress and you can borrow one of my suits." So they did just that.

When Mike started his doctoral work in 1973, the chemical industry was in the throes of change. Post-World War II manufacturers had concentrated on hydrocarbon production. Processes often employed distillation of ideal mixtures. By 1960 the phase behavior and design of these systems were very well understood. Beginning in the 1960s, however, the emphasis within the chemical industry began to shift away from hydrocarbons and toward chemicals, *e.g.,* specialty chemicals, polymer precursors, etc. These chemical processes were more complex, most often involving nonideal mixtures, the phase behavior of which was not well understood. Thus, there was little or no predictability with regard to process design. Separations systems resulted mainly from trial and error.

To devise a systematic way of describing nonideal mixtures so they would be susceptible to mathematical analysis, was nontrivial. A completely new way of thinking was needed for the design of these distillation processes, especially those containing azeotropes. Mike found a way to represent the phase diagram as a set of paths or curves in space employing a set of differential equations. The resulting set of curves produced an equivalent residue map for the particular system. In his doctoral dissertation, he formalized this methodology, known as Residue Map Analysis, whereby a set of curves can be developed for each and any phase diagram.

Mike knew what he wanted to do upon completion of his doctorate—he wanted to be an academic. Moreover, he really wanted to be in the United States. He had an American wife and he'd hitchhiked around the States a bit as a college student. So, while in his third and last year at Cambridge, Mike started applying for academic positions in the U.S. In England there had been no pressure to publish, so Mike had no papers to his name. As a result, no one in the U.S. had heard of him. Moreover, few had even heard of his young advisor, Perkins, or of the theory Mike had developed. So, sadly, Mike received a fistful of rejections and no invitations to interview for a position.

At Easter time, one of the Cambridge faculty stopped by Mike's office to tell him that, "Professor Aris is coming to town next week and wants to take you to lunch." Rutherford Aris, at the height of his distinguished career, was Head of the Chemical Engineering Department at Minnesota, which had already rejected Mike for an advertised job. Mike's officemate, Rob was studying an Aris paper at the time and having some difficulty with it. When Aris arrived, Rob jumped up and exclaimed, "Prof. Aris, I have read your paper and I was hoping to ask you a few questions about it." Aris responded, "If you have read that paper recently, you surely know more about it than I do!"

Aris and Mike went to lunch, and Aris offered Mike "a nonrenewable position for one year only to teach," *i.e.*, a teaching postdoctoral. Aris was going to CalTech in the fall of 1976 on a fellowship and needed someone to teach his course. The catch was that Mike had to be in Minnesota by August 1st—with his thesis submitted.

Mike decided he could do it. In order to finish by August, he had to work seven days a week, from 7 in the morning until midnight each day. His friends would come around regularly to take Peggy out to the local pub while Mike stayed home and slogged away.

Mike learned one of the more valuable lessons of his life during that period of time. He and Peggy had a beautiful second-story apartment at Trinity, and Mike had set up a desk for himself in a big bay window. Both the typed and the handwritten copies of his almost-complete thesis were on the desk when one afternoon he and Peggy decided to go downstairs to a phone box in front of their apartment to make a call. They opened the phone box door and saw a package with a clock strapped to it. They immediately closed the phone box door—as gently as possible—since the IRA bombing campaign in England was at its height at that time, and ran to a nearby hotel and called the police, who arrived on the scene within three minutes. Mike and Peggy were instructed to hold up traffic while the police evacuated the whole block. A robot was brought in to blow up the suspicious package, and, fortunately, there were no explosives. But Mike had come too close to losing all copies of his thesis, and to this day, he never keeps just one copy of anything. He backs up his work in multiple places.

On August 8, 1976, Mike submitted his thesis ("only a few days behind schedule"). The next day, he and Peggy leased a large shipping container, packed up their things, and flew to New York the next day. After spending a few days with Peggy's parents, they bought a VW minibus and drove West, arriving in Minnesota during a mid-August heat wave.

On Mike's first day on the job, he rolled in to the department at a respectful hour (at any rate, for a British university in August), around 11 a.m., and was talking to Aris and some others when at 11:30 they said, "Let's go to lunch." Mike, not thinking about the impression he was making until later, replied, "I just had breakfast." He was a fast learner, however—the next day he was at the office before 8 am.

The working day schedule was not the only way in which Minnesota differed from England. Mike and Peggy had also never experienced the kind of heat they were subjected to throughout August and into September. What's more, they didn't have the appropriate clothes for it. Then, in October, the coldest weather they had every experienced arrived, and they had no clothes for it either. At the beginning of November, Peggy's mother called to ask, "What would you like for Christmas?" Mike and Peggy weren't shy about responding, "goose down jackets. . .but please don't wait until Christmas, send them today."

"In 1976, I came to America for one year. It's been the longest and best year of my life."

When Mike flew home over Christmas to defend his thesis and Peggy went to New York to see her family, they did what they had always done in England to economize. They turned off the heat in their apartment. Upon their return in January, they were greeted with a frightful mess—the water pipes had burst. Another lesson learned!

The University of Minnesota turned out to be a wonderful career break for both Mike and Peggy. The Chemical Engineering Department had many of the best people in the world and they were wonderful colleagues. Mike learned a great deal, both through his teaching and through his interactions with other members of the department. He also wrote his thesis papers during this period. Meanwhile, Peggy, who had her undergraduate degree in classical Arabic, talked her way into Minnesota's top-rated Institute for Child Development and became a PhD student.

Mike and Peggy left Minnesota in the summer of 1977 as a two-career family and went to the University of Massachusetts at Amherst where Mike was extremely happy. The students he attracted were really first class. He had ". . . a great run. I can't imagine being able to do better work or publish better papers or work with a better colleague than Mike Malone anywhere else in the world. Our students did not leave much on the table." Mike and Peggy's first child, Sarah, was born in 1981 and Peggy finished her PhD in 1983. In January of 1984, Mike and Peggy went to Berkeley where Peggy had a fabulous postdoc position in the Psychology Department and Mike did a sabbatical. Although Peggy's mentor wanted her to stay, they returned to U Mass in January 1985. Their second child, Max, was born that same month.

Mike was certain he would never leave U Mass. He loved his friends, his colleagues, and his house and land (all seventy acres). And during the time he was Department Head (1989-1997), he'd helped to build up the department. Most of the young faculty that were hired during this time won NSF Career Awards; two won Packard fellowships. In 1999, Mike took a six-month sabbatical. Moreover, U Mass gave Mike one of their Conti Fellowships—a very special, highly prized, yearlong, and full-salaried fellowships that doesn't interfere with sabbatical (or other) clocks. Mike spent most of the year working on the textbook. He also traveled around, giving talks. One of them was given at UC Santa Barbara where the faculty expressed an interest in having him join them. After many months of anguish Mike, made a return visit to Santa Barbara in February 2000, and this time Peggy accompanied him. Early one morning (which happened to be wedding anniversary), they were sitting at a beachside restaurant enjoying the view, and Peggy leaned over and said, "You can leave me here."

The more Mike visited, the more he appreciated the people and the work at UCSB. Not only were the professional aspects enticing, but the location was physically perfect, so in September 2000, the family moved to Santa Barbara. Mike, who had already started to shift his research focus away from distillation, found that UCSB was perfect for emphasizing his new interest, the crystallization of organic materials. He believes that in order to develop a great process, engineers really need to understand the chemistry. UCSB is a world center for materials and Mike, still very much an engineer interested in the big picture of process design, is trying to build a bridge between materials and engineering. At UCSB, the right mix of colleagues, courses, and facilities provide the perfect environment for his interests and his students. Five of the seven people in Mike's group are currently working in solid-state to explain the evolution of crystal growth.

In 2004, Mike is happily working in that niche in the design world which is the bailiwick of chemical engineers. Peggy is a case manager at Santa Barbara's Devereux Center, a nationally known residential facility for the developmentally disabled. Sarah is a Junior at Smith College in Northhampton, MA, majoring in economics, and Max is a freshman at UC Berkeley, majoring in political science. To sum it all up, Mike says, "In 1976 I came to America for one year. It's been the longest and best year of my life." ❒