

## Robert C. Armstrong of MIT



photo/Webb Chappell

*Robert C. Armstrong at MIT's Chemical Engineering Department.*

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Yesterday's good answer is today's great question. That's what Bob Armstrong of MIT tells his ChemE students. Whether it's a textbook problem in fluid mechanics or a global problem in carbon emissions, answers are the best place to start asking, "What were their methods?" "How can we account for the unexpected?" "Where can we go from here?"

The Chevron professor of chemical engineering at MIT and winner of the field's most prestigious awards, Bob has been at the forefront of polymer fluid dynamics and transport

phenomena for more than 30 years. In 2009 he was elected a member of the Board of Directors of the American Institute of Chemical Engineers (AIChE), and he has held a leadership role in addressing the world's energy problems, serving as deputy director of the MIT Energy Initiative (MITEI) since 2006.

A native of Baton Rouge, Louisiana, Bob grew up immersed in the new technologies that were responding to America's needs for materials and energy. Innovations in the chemical, petroleum, shipping, and other industries were burgeoning. With its port on the Mississippi and its relative safety from hurricanes and floods, the state's capital city embodied America's post-war boom.

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Esso (now Exxon) and Shell had great jobs for chemical engineers—Bob’s father, Wallace, worked for Ethyl Corporation, a major chemical company, throughout his career. Cars, malls, and homes hummed with air conditioning. In 1960, when Bob was 12, crude oil cost \$3.00 a barrel. Gasoline was 31 cents a gallon. “I took energy for granted for most of my life,” Bob says.

The energy crisis Bob now works to resolve took root in 1960, too. In a move that attracted little attention at the time, Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela formed the Organization of Petroleum Exporting Countries (OPEC). American energy consumption and dependence on foreign oil would affect global industries, economies, politics, and energy supplies in years to come.

Like most Americans, Bob’s personal life was more affected by events in the United States than by OPEC or the Middle East. The Vietnam War coincided with his high school and college years—in the 1969 draft lottery, Bob’s number was 308. His family, active in church and civic life, were known in Baton Rouge as inclusive and pro-integration. His parents, Wallace and Eileen, received wide local recognition for their community service.

“As a youngster, I benefited from a culture of successful engineers and growing industries. My family was very service-oriented. I look on what I do today as service, as giving back to society,” Bob says.

A gifted and serious student, Bob focused closely on school. In summertime, he played tennis and golf and water- and shoe-skied on Louisiana’s Amite River and on Lake Maurepas, near Baton Rouge. “You had to hold those short skis just so,” he says. “I got pretty good at it.”

When he headed off to Georgia Tech in 1966, he already knew he would major in chemical engineering. “It was a great way to combine the subjects I liked best—math, physics, and chemistry,” he says.

But don’t let Bob’s modesty and studious demeanor mislead you. He has a lively wit and love of adventure, warns Debbie Armstrong, Bob’s wife of 40 years and also a Baton Rouge native.

“Bob found out he loved math when he got sent to detention and met the math teacher. He and a friend once blew up a shack in a bad chemistry experiment,” she recalls. “When we were in high school, he was a great lab partner. At the same time, he was a drummer in a rock group—The Capers—that featured him playing solo drums in ‘Wipe Out!’ ”

## GEORGIA TECH

When he got to Atlanta, Bob was pleasantly surprised to discover a familial aspect of the chemical engineering community: Tech ChemE professor Jesse Mason had taught Bob’s father at the University of Florida. “That’s one of many connections I had with my father,” Bob says. “And I had a similar experience at MIT: I taught the daughter of two of my former ChemE students.”

Characteristically, Bob devoted his college years to academics. He kept up his musical life, too, playing snare drum for the Geor-



*The Capers’ rockin’ drummer.*

gia Tech Marching Band’s half-time shows at football games. “That was big-time sports—uniforms, full stadiums, TV coverage. The Yellow Jackets even went to the Orange Bowl,” he says.

With typical understatement, Bob says he did alright at Georgia Tech—meaning, he earned A’s in all his courses; passed the grueling Tech swimming test with its bizarre requirement that students swim hog-tied for one hour; and drummed for the band. He did get one F, in track. “I had no endurance for distances,” he reports.

He spent his college summers working in the energy industry, working for the Gulf South Research Institute; Kaiser Aluminum; Ethyl Corporation, now the Albemarle Group; and at Esso Production Research (now Exxon) in Houston, where he studied bottom-hole samples to discern how much oil was left in the ground after initial production.

His other experiences with oil production were more the sportsman’s. Bob and his family enjoyed fishing for red snapper off the Gulf Coast, boating from Grand Isle or Empire out to offshore drilling platforms. “It was great. Fish just love those platforms,” he says.

## THE ICY NORTH

Bob and Debbie married in August 1969. A year later, they packed their blue 1970 Chevrolet Monte Carlo, a graduation gift from Bob’s parents, loaded their U-Haul trailer, and drove from Houston to the University of Wisconsin, Madison. Their destination, renowned as an epicenter of the student anti-war and environmental movements, would have felt far more foreign had not a “catastrophe quieted everything down,” Bob recalls.



Bob and Debbie's wedding, August 1969.

"Protestors had bombed the Army Math Research Center, killing one and injuring others, two days before we arrived. Marches and demonstrations had stopped. It wasn't so different from Baton Rouge."

In their first northern winter, the newlyweds came to love Madison's frozen lakes—once they learned how to stay warm. "What do Louisianans know about cold? One morning, we woke up to find it was minus 27 degrees outside. The paint had literally fallen off our car," Bob says.

According to Professor Emeritus Robert B. Bird of Wisconsin's Chemical and Biological Engineering Department, Bob's graduate career got off to a slow start. In Bird's course on applied mathematics in chemical engineering, the new student looked "rather sleepy. But I soon learned that I could depend on him to come up with correct results."

In 1968, Bird had shifted the aims of his research program from a purely continuum approach to polymer fluid dynamics to a molecular approach. "Bob Armstrong and Ole Hassager, now ChemE professor at the Technical University of Denmark, were among the first students to tackle this very difficult and chal-



Fishing with sons David and Eric.

lenging field. In a sense, the three of us grew up together in a new field," he says.

Bob completed his Ph.D. thesis, *Obtaining Constitutive Equations from Molecular Models*, in 1973. Debbie typed it on a Smith-Corona typewriter while Bob hand-drew the equations. Just before that was done, he and Hassager proposed an astonishing project, Bird recalls.

"The two came into my office with rather odd grins on their faces. They told me, 'We'd like to write a book with you.' I had a set of very rough notes for my classes, and they wanted to volunteer to turn the notes into a book. It would involve an immense amount of work, but they did not appear to be dismayed," he says.

Bird knew whereof he spoke. He is co-author of the 780-page *Transport Phenomena* (1960) and the 1,200-page *Molecular Theory of Gases and Liquids* (1954), known around ChemE as the "Green Monster."

Undaunted, the three roughed out an outline for *Dynamics of Polymeric Liquids* ("DPL" to its fans), the first textbook on the subject, which was published in 1977. DPL's second edition appeared in 1987 and was named a Citation Classic in 1988 in recognition of how frequently it is cited in papers and books. It remains in print today. Significantly, the authors have remained close, Bird notes.

"Book-writing is a very severe test of personal relations. There were heated discussions and technical disagreements. Bob was invariably pleasant and easy to work with," says his advisor-turned-colleague.

## ON TO MIT

In 1973, Bob accepted an assistant professorship in chemical engineering at MIT, where in 1888 the nation's first four-year chemical engineering program had been founded.

He and Debbie, now a clinical social worker, moved to the land of the Red Sox and the New England Patriots, settling in Lexington, Mass., a community known for its green space, good schools, and youth sports programs. Their son David was born in 1976; son Eric, in 1979. Over the next 10 years, Bob's growing leadership skills, his love of sports, and his family's example of community service would take him out to the ball game as a Little League coach and, later, president of the local league.

Eric caught baseball fever early, playing center field on a varsity team in high school and in Division One baseball at Lafayette College in Pennsylvania. His parents were in the stands for many of his AAU and college games.

Now a U.S. Marine Corps pilot, Eric was deployed in Iraq in summer 2008, and he headed out with the 24th Marine Expeditionary Unit at the beginning of 2010. "Eric loves adventure and the outdoors. His patriotism led him to enlist after 9/11," Debbie says.

According to Debbie, teaching and research in chemical engineering sometimes inspired Bob's parenting in funny, creative ways.

"When the boys were little, Bob would talk to them about how gunky and goopy materials worked. He'd illustrate by sculpting with peanut butter and squirting toothpaste out of the tube," she says.

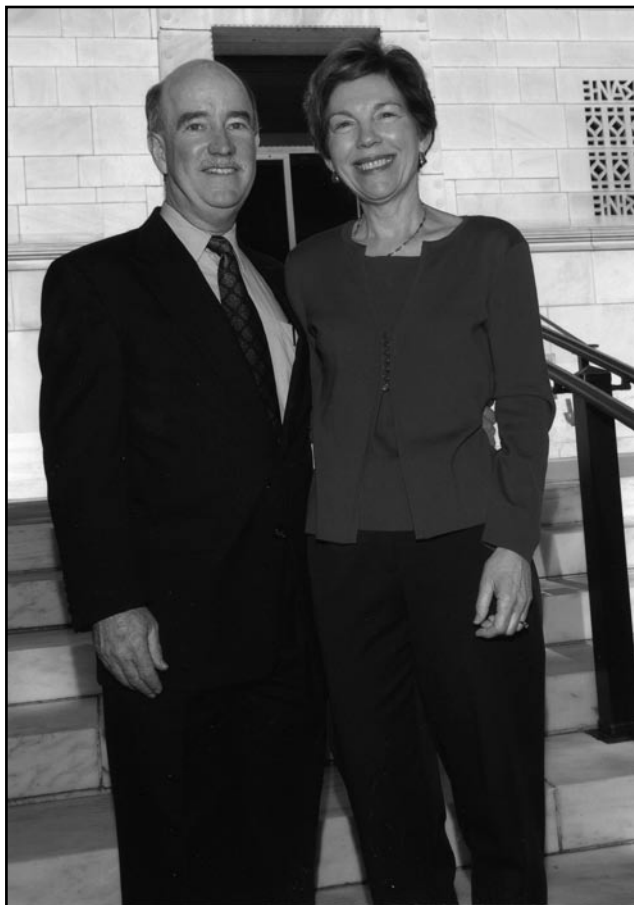
Bob recalls with amusement, "They had an action figure called Stretch Armstrong. His superpower was super-stretchable arms—a great example of viscoelasticity!"

In conversation, Bob readily cites ordinary household products—shampoo, ketchup, mayonnaise—as examples of complex fluids. He nimbly uses whatever is at hand—a pen, a glass of water, and a little polymer—to show how a non-Newtonian fluid can be lifted out of the glass with the pen. Try that with water!

"Sometimes I connect what the students are seeing to history," Bob says of his ChemE lecture style. "I tell them, this isn't new: The Roman historian Tacitus described the same mechanics. When they harvested bitumen, a tarry substance, they found it would siphon itself into a boat—very different than water."

## A GIFT FOR TEACHING

Knowledgeable and enthusiastic, Bob shone as a new teacher. During his first three years at MIT, he won the Outstanding Faculty Award in 1976 and the DuPont Young Faculty Award for 1974-75 and 1975-76.



*Bob and Debbie, 2009.*

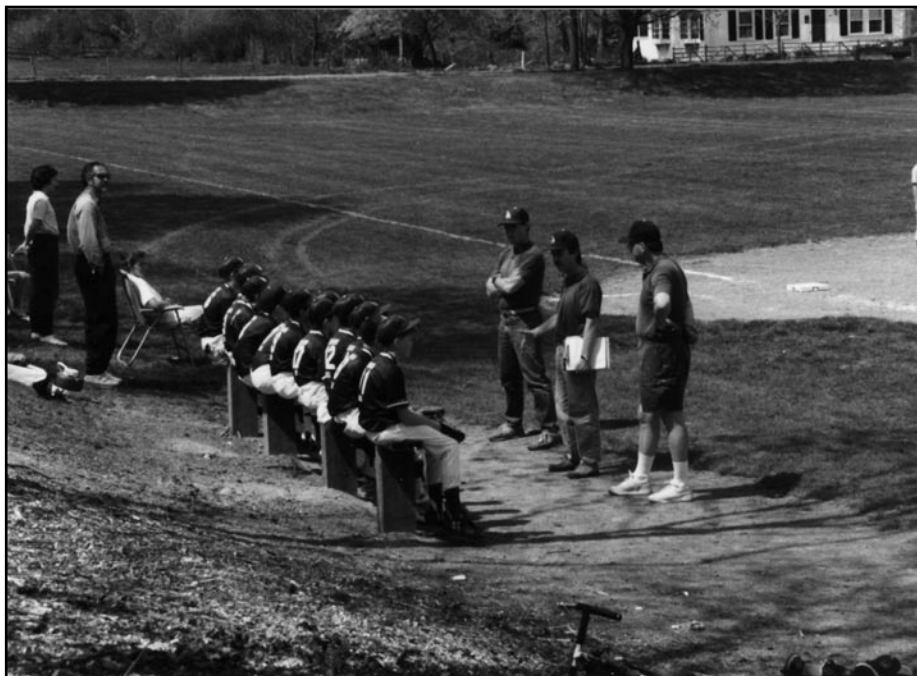
Former student Zubair Anwar (MIT Ph.D. 2008) is an associate at McKinsey & Co. In his graduate classes on transport phenomena and dynamics of polymeric fluids, "Bob often stressed that most analysis was a departure from known analytic solutions. He encouraged us to propose an answer and test its validity with fundamental equations," Anwar recalls.

Antony Beris (MIT Ph.D. 1985), professor of chemical engineering at the University of Delaware, says Bob "inspired us to give our best."

More than inspiring students to do their best, Bob has sometimes inspired students to do things they'd never considered—like include a trip to a balloon festival on a research consultation visit.

Beris had gone to meet with Bob, who was working at Exxon Corporate Research in New Jersey. "He included me with his family at the festival. He was very cordial and open with his graduate students. He gave me confidence to pursue an academic career on my own."

Promoted to full professor of chemical engineering in 1988, Bob continued to publish research in the journals of *Rheology* and of *Non-Newtonian Fluid Mechanics* (among others),



*Little League Coach Bob, with clipboard.*

teach, serve as a respected and demanding thesis advisor—and show up for Little League games.

Micah Green (MIT Ph.D. 2007) guesses it's Bob's sense of humor that helps him balance it all. "He has a corny joke chambered for any occasion. Once he told a huge audience of professors and alumni a groan-worthy joke about a duck buying Chapstick at a store and telling the cashier to 'put it on his bill'," says Green, now assistant ChemE professor at Texas Tech.

Susan Muller (MIT Ph.D. 1986) is professor of chemical engineering and associate dean, Graduate Division, at the University of California, Berkeley. Bob, one of her thesis advisors, was "a great classroom instructor. As a research advisor, he was incredibly patient and generous with his time. I'm not sure I am as patient with my students, but I think of that experience as a touchstone," she says.

In 1992, Bob won the prestigious Professional Progress Award for Outstanding Progress in Chemical Engineering, a prize recognizing significant contributions to the science of chemical engineering through discovery, invention, or service to the field.

Outside of ChemE, Bob's spirit of discovery is replenished today, as it was when he went fishing around those Gulf Coast drilling platforms, by time and activity outdoors, preferably wilderness areas.

"I dream of hiking," he says. "Debbie and I have climbed half of Mount Desert Island's 26 mountains. Beautiful scenery, vistas of ocean and other mountains, followed by popovers and tea—that's hardly roughing it. It's my favorite place."

One of Bob's memorable outdoor adventures took place in 1993, when he and his son David joined Bob Bird and John Wiest (currently Associate Dean of Engineering at the University of Alabama) for a two-week canoe trip in Quetico Provincial Park in western Ontario, Canada. "We had a great trip, but the weather didn't cooperate," Bird says. "Once, it poured all day, and we had several difficult portages. Bob held up quite well as an outdoorsman."

David held up best of all, his father and Bird recall. "Our worst day—a mile-long portage in the rain—was his favorite," Bob says. "He liked that strenuous challenge."

Later, Bob tried to return his advisor's favor by taking him on a climbing trip to New Hampshire's Mount Monadnock. Sleet and snow

above the tree line defeated them before they reached the summit; both men describe the cold, thwarted hike as "interesting," like an experiment that goes awry yet opens vistas for new work.

You might say Bob hikes as he teaches. He's well prepared, enthusiastic, a good map in hand—and open to surprises.

## FROM TEACHER TO LEADER

In 1996, Bob was named head of MIT's department of chemical engineering; he served in that role until 2007. As department head, Bob focused on, well, everything—teaching, research, and leadership. Yet he maintained his naturalist's ability to take in a wide landscape—the big picture—while managing challenges and change.

In the late 1990s, exciting developments in materials science and in biology raised significant questions for Bob as an academic leader. How could the department engage in these new disciplines yet retain its focus? More broadly, how could the field expand to include new areas and retain its professional identity?

These new questions called for both patience and innovation. Bob's leadership of the department included hiring 11 MIT ChemE faculty and introducing a new undergraduate program, Course 10-B, Chemical-Biological Engineering. This has proven to be a magnet for undergraduates: just over half of the department's undergraduates are now enrolled in it.

Bob's vision and commitment to ChemE education extended beyond MIT's Infinite Corridor onto the national scene when he became department head.

*Thesis advisor  
and fellow  
outdoorsman  
Bob Bird of  
the University of  
Wisconsin,  
Madison, left,  
with Bob.*



Active in discussions about the profession's identity and how it should evolve, he led one study on the subject that was funded by the NSF, and he was prominent in AIChE deliberations on the topic. In 2006, these culminated in his publishing, as sole author, "A Vision of the Chemical Engineering Curriculum of the Future" in *Chemical Engineering Education* and a chapter by the same name in *Chemical Engineering: Visions of the World*, which was published in both English and Chinese.

During his first year in administration, Bob traveled widely on behalf of the field. More than 25 speaking engagements took him to universities in Britain and Canada and across the United States; to industries including General Electric, Eastman Kodak, and Dupont; and to national conferences of the AIChE and the Society of Rheology.

## **OLD SCHOOL TIES, NEW GLOBAL TASKS**

Back in Georgia, the Rambling Wrecks kept track as Bob's career advanced, naming him to the Georgia Tech Academy of Distinguished Engineering Alumni in 1996.

It had been 30 years since he arrived at the Atlanta campus, eager to get down to work. He enjoyed success as a professor, researcher, administrator, husband, and father. College-sports-wise, he had switched loyalties: The Wrecks' former Marching Band drummer now roots for LSU baseball and football teams, along with his Baton Rouge family and friends.

Plus, he'd erased that pesky F in track. "Right after I defended my thesis, I took up jogging and long-distance running as a hobby. Five or six miles became easy," he says.

Today, Bob keeps fit by working out four or five times a week, doing his own landscaping and gardening at home, and walking with Josie, the family's black Lab. (They also have a cat, MidKnight.)

In 1999, the drum set came out once more, for a rock and roll faculty skit at a department Christmas party, according to Barry Johnston, senior ChemE lecturer at MIT. Bob recalls the performance as "a good chance for students to laugh."

Outside academic departments and beyond national borders, the global energy crisis cast a pall over many Y2K galas. By 2000, world leaders and scientists were hotly debating the gravity of climate change and energy needs. In 1997, the Kyoto Protocol set binding targets for reducing greenhouse gas emissions, to be implemented between 2008 and 2012.

In 2005, as the Protocol went into effect, ChemE professor Bob Brown, then-MIT Provost and now Boston University President, announced the formation of MIT's Energy Research Council (ERC). Bob and Ernest Moniz, former undersecretary for the U.S. Department of Energy and an MIT professor of physics, co-directed the ERC. They were charged with crafting MIT's overall energy initiative and coming up with a structure to sustain it.

Bob took up that challenge as he has so many others — methodically and thoroughly — while pursuing his teaching, advising, and research. Whether approaching a research problem or roughing it in the rain, he sticks with the "hallmarks of a careful theoretician. Establish the basic principles, clearly explain your methods, then make systematic advances towards your goal," says Bob's former student, Gareth McKinley (MIT Ph.D. 2007). "Old school, some would call it."

Ever enthusiastic about research and innovation in ChemE and energy studies, Bob acknowledges he does rely on one old-school technology—the blackboard. “Once I worked all night to prepare PowerPoint slides, only to forget to bring them to class. The students were so relieved I used the blackboard! PowerPoints can move too fast for real learning,” he says.

## THE BINGHAM MEDALIST

In 2006, Bob’s colleagues and peers presented him with the prestigious Bingham Medal. Sponsored by the Society of Rheology, the Bingham Medal recognizes outstanding research contributions to the field.

Bob’s published research provides a record of those contributions. He has co-authored more than 70 papers with Brown in a particularly productive collaboration.

Bob and Brown also co-advised numerous MIT graduate students. “They formed a unique team,” says McKinley. “Working for ‘Bob and Bob’ was a statement that carried a lot of weight and commitment.”

Bob’s Bingham lecture, “Rheology and Energy: What Can Rheologists Do?” reflects his growing commitment to bringing his academic research and energy research more closely together.

“The energy business is basically moving fluids around the world. Understanding how they move is crucial. Rheologists work to understand how sea ice breaks up due to climate change and how the stringy slurry from bio-fuel production can be pumped from place to place. The field has plenty of subsurface flow problems to tackle, too,” he says, his excitement clear at the prospect of new challenges.

Certainly, Bob’s research has contributed to the next generation of leaders in ChemE and related research.

McKinley, now head of MIT’s Non-Newtonian Fluid Dynamics Research Group, describes his lab’s experimental work on systems ranging from bread dough to spider silk to hagfish slime as “heavily influenced” by Bob and Brown.

Beris of the University of Delaware currently studies modeling and simulations of complex flows, a direct outgrowth of Bob’s research on the behavior of complex fluids. And, according to Green, Bob’s theoretical work helps provide context and direction for his own research on novel nanomaterials like carbon nanotubes and graphene.

Bob’s enthusiasm for passing on his commitment to ChemE education and research is contagious. His eyes light up when he describes his vision for linking students’ skills and altruism to grand problems in energy, health, water, and security.

“I’d love to have student groups work on projects like cleaning up Superfund sites or designing concentrated solar power plants,” he says, “I’d like to say to them, ‘This is one of the world’s big problems, and we need your help.’ I’d like

***Ever enthusiastic about research and innovation in ChemE and energy studies, Bob acknowledges he does rely on one old-school technology—the blackboard.***

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them to leave MIT with a belief they can solve anything and a sense of responsibility to do so.”

Between 1998 and 2006, Bob had to believe he could solve anything: He balanced his roles as teacher, advisor, researcher, and department head while traveling almost constantly. In 2004 alone, he traveled to China, Germany, and South Korea to speak on chemical engineering research or education.

Meanwhile, as Bob traveled around the world, oil prices were traveling out of this world. In 2007, the price of crude oil surged over \$100 a barrel. Gasoline hovered at \$3.00 a gallon—market events unthinkable just a few years before. Carbon footprints, solar panels, bio-fuels, algae-based smog-eaters—a new lexicon of concern about fossil-fuel consumption sprang into popular use.

A different man might have tooted his own horn to say he’d told them so. But that’s not Bob. Back in 1999, he and Debbie got rid of one of two family cars to conserve another scarce resource—time. Then, as now, Bob’s busy schedule left too few moments to indulge his love for books.

Since then, Bob has taken public transportation—a bus, then a train—so he can read and work during his commute. When he flies, he’s always got a book. He enjoys mysteries that feature science or scientists; he prefers authors Clive Cussler, Dan Brown, John Grisham, and Michael Connelly. Bob also enjoys the occasional nonfiction work, such as Jared Diamond’s *Guns, Germs, and Steel*.

Bob’s wide reading and boundless curiosity add spice to his lectures, keeping students interested, he says.

“My advice to a new teacher is: Connect the material you’re covering to current global problems. Invite your students to get involved in thinking about the world’s future.

“Another strategy is to bring in history. Students enjoy my illustrating non-Newtonian fluids by referring to the ancient Romans’ siphoning bitumen. They like learning that the Deborah Number got its name from the Biblical Book of Judges,” Bob says. “It opens their eyes.”

## ENERGY STUDIES, ChemE AWARDS

The MIT Energy Initiative (MITEI) was established in 2006. Bob and Moniz serve as deputy director and director, respectively; they coordinate MIT’s existing energy activities and guide the development of relationships with other institutions, industry, and government agencies.

In 2008, Bob was elected to the National Academy of Engineering, a measure of his scholarship and leadership in academia, according to Bird. The NAE praised Bob for his “outstanding research on non-Newtonian fluid mechanics, co-authoring landmark textbooks, and providing leadership in chemical engineering education.”

That year, he presented the Barnett F. Dodge Distinguished Lecture at Yale, on “The Energy/Environment Challenge and MITEI,” and the L.T. Fan Distinguished Lecture at Kansas State, on “The Global Energy Challenge: Opportunities for Chemical Engineering Research and Education.”

Bob’s current projects often combine ChemE and energy research. He and McKinley are working with Chevron on deposition of waxy crude oils on surfaces of pipes in deepwater drilling operations, for example.

Since assuming the deputy directorship of MITEI, Bob has lectured widely on energy and chemical engineering education. He devoted a sabbatical year to establishing MITEI, traveling to Saudi Arabia, Italy, Spain, China, and Singapore on the Initiative’s behalf.

In spring 2010, Bob returned to the MIT classroom to co-teach a graduate class, Macromolecular Hydrodynamics, with McKinley and to develop a new ChemE senior design module on concentrated solar power.

Looking ahead, he’s quick to cite great examples of how innovative approaches to ChemE education, supported by MIT’s Energy Initiative, can prepare students for their futures in the field.

The 2007 MIT Coal Study is one such innovation, he says.

“The Coal Study compared different strategies for carbon

capture and sequestration (CCS). ChemE senior design students did all the economic evaluations of capture technologies. They had to see energy issues from new perspectives, and the result was a rigorous and consistent economic analysis of one of the world’s biggest problems ... and a sense of the relevance of their education.

“MIT and MITEI are bringing together faculty and students from every discipline to focus on energy. We’re getting out of disciplinary silos and traditional textbooks. There are no ‘solve the problems in chapter 10’ in the real world. We’re facing complex and urgent global problems,” he says. The MIT Energy Studies Minor is a great example of this new interdisciplinary approach.

Ever the ChemE educator, Bob believes ChemE students need a balance of academic and international experience to take on those global problems. Some MIT ChemE students, for example, work at Novartis in Switzerland, at BP in Britain, or at a sugar refinery in India to enhance their abilities to solve pressing world problems.

“U.S. solutions don’t always apply in other cultures, including the developing world. Even if graduates work in a big international energy company, they will need to adapt to local cultures,” he says.

Whether in a classroom, a lab, or an unfamiliar culture, he wants chemical engineers to be ready to ask themselves ‘What kinds of new solutions can we synthesize to solve society’s big challenges?’ ”

Those who know him have no doubt that Bob’s impact on the energy world will be at least as great as his impacts have been in the fields of rheology and education. □