ChE at . . .

The University of Arizona

Paul Blowers,
Jim A. Field,
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and Reyes Sierra

University of Arizona faculty member Armin Sorooshian lectures on heat exchangers in fluid flow and heat transfer.

The University of Arizona was founded under the Morrill Act as a land grant university in 1885, 27 years before the state of Arizona entered the union. Classes began in 1891 with 32 students, and due to the lack of high schools in the territory, the university performed outreach by maintaining a separate set of preparatory courses to allow students to enter the university. Since those early years, the university has grown to offer degrees in more than 300 separate fields of study with a total student population of more than 29,000 undergraduate and almost 7,000 graduate students.

Chemical engineering at the University of Arizona was founded in 1957 as part of the School of Mines by Don H. White, and he became the first head of the department in 1958. The first graduating class left the department in 1960 with eight graduates, while the first M.S. student, Harry Hyatt, graduated in 1961 and the first Ph.D. was earned in 1964 by Richard Edwards. Don White remained department head until 1974 when Joseph Gross became head for six years. Gary Patterson led the department from 1985 until 1990 when Thomas W. Peterson took over the reins for seven years before becoming dean of the College of Engineering. During Tom Peterson's tenure, he and Ray Sierka led the efforts to merge the chemical engineering faculty with the environmental engineering faculty, and those efforts were successful on July 1, 1993. Jost Wendt was head from 1998-2005 before Glenn Schrader, recruited from the National Science Foundation, led from 2006 until 2009. In 2009, an internal search led to the election of James A. Field, who began his term as department chair, a new leadership format.

FACULTY AND RESEARCH INTERESTS

The department currently has 15 full-time faculty members who contribute to the academic and research vitality of the campus. This past year, research expenditures for the department were almost 3.4 million dollars.

Table 1, on page 4, lists the faculty, their Ph.D.-granting institution, and their current research areas.

As one can see in Table 1, many faculty emphasize research at the interface of chemical and environmental engineering, which was the primary driver of merging the faculty of the

two departments, and the origin of much of the attraction of interest to the department. The focus on these synergies has also led to the strong presence of environmental topics in the undergraduate curricula as discussed in the next section.

The department has strong involvement or leadership positions in two prominent research centers. The Semiconductor Research Center (SRC)/ SEMATECH Engineering Research Center for Environmentally Benign Semiconductor Manufacturing is led by Farhang Shadman, who originally founded the center with collaborators at Stanford and MIT through the NSF Engineering Research Center initiatives. This center has remained active as a vibrant research catalyst and continues to focus on semiconductor manufacturing while diversifying into broader nanotechnology issues. The center is now in its 15th year, five years after the NSF support was sunset. The U.S.-Mexico Binational Center for Environmental Science and Toxicology is co-directed by Jim Field, chair of the department. The mission of the Binational Center is to provide and support environmental science and toxicology training, research, and policy development as well as facilitate a dialogue between investigators and stakeholders on risk assessment and remediation of hazardous environmental contaminants prevalent in the Border region. In addition to these centers, faculty members collaborate with researchers in public health, environmental sciences, atmospheric sciences, optical science, material science, chemistry, physiology, toxicology, and pharmacy.

Old Main: The first building constructed on the campus and still in use.

THE UNDERGRADUATE PROGRAM

The undergraduate program had a total of 177 registered majors at the start of Fall 2010, with the recent graduating class having 38 undergraduate students. Enrollment at the sophomore level has risen from 55 students three years ago to 92 students in the most recent fall semester. The student body in chemical engineering continues to be diverse with the recent graduating class having 35% female, 13% Hispanic, 2% Native American, and 4% African American students. While students predominantly come from Arizona, there are many students from California due to the relatively low tuition of our university. International students make up less than 5% of each class at this time, although a new China 2+2 program with Fudan University and Shanghai Jiao Tong University was initiated in 2009 that allows students to obtain degrees from their home institution and the U of A in four years. It is anticipated that approximately eight students per year will enter this program within the next three years.

The B.S. degree program is accredited by ABET and is undergoing the normal review process. While much of the curriculum is traditional, there are several unique aspects. Students take two units worth of computer programming in Visual Basic after completing a three-unit freshman programming course with C+. A subsequent core course introduces Matlab applications in the context of numerical methods. A three-unit upper-division core course is dedicated to introducing students to biotechnology as well. Instead of having a senior-level three-credit Unit Operations Laboratory course, the department moved to a distributed three-semester series of one-unit modules spread out through the junior year and the first half of the senior year. This change allowed for faculty to now also introduce ChemCAD in the junior year and strengthen Matlab training. This change also moved many of the experiments into the same semester the theory was being taught, which makes pedagogical sense. The transport phenomena course sequence consists of two traditional courses that cover the basics of fluid mechanics and heat and mass transfer, followed in the second semester of the junior year by a comprehensive transport phenomena course based on Bird, Stewart, and Lightfoot's classic textbook.

The strong chemical engineering core is supported by many electives, with offerings in rheology, surface science, atmospheric science, semiconductor manufacturing, and bioreactor design. On the environmental side, classes are offered in water chemistry, wastewater treatment, hazardous waste management, and pollution control. Many students use these opportunities to prepare for graduate work in environmental engineering or for environmental consulting jobs.

Our mission is to:

- provide excellence in university-level teaching of chemical and environmental engineering to a broad diversity of students
- prepare students to be competitive in the global job marketplace through mentoring, research, and internship opportunities
- pioneer quality research that advances engineering fundamentals and promotes innovations in technology development in areas of:
    - o energy
    - o environmental technology
    - o biotechnology
    - o nano-scale device manufacturing

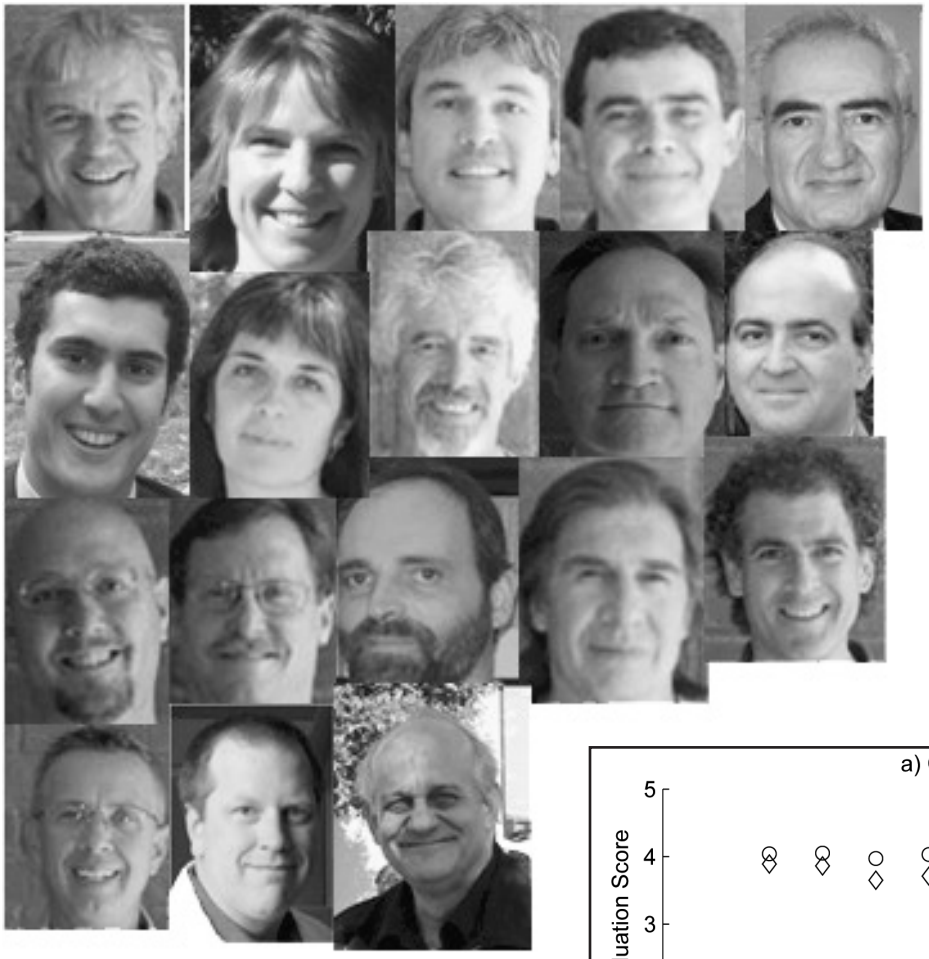
Advising and instructional efforts are strong across the department. Students are directly advised by faculty, which allows for close mentoring of each student and the ability to solve student difficulties as they arise. Constant communication with students inside and outside the class, through research and departmental picnics and coffee hours, has led to one professor being selected for the Excellence in Academic Advising Faculty Advisor Award in 2007, which is given to one faculty member at the University of Arizona each year. That faculty member then went on to be named one of the best four Outstanding Faculty Advisors in the United States as selected by the National Academic Advising Association.

Faculty teaching evaluations are consistently very high within the department. Figure 1a shows faculty teaching-effectiveness and amount-learned scores (on a five-point maximum scale) for all core courses required in the department. Teaching course-evaluation scores are similarly high in the elective courses, as seen in Figure 1b. As a point of comparison, many departmental averages on these scores are around 3.5 to 3.6. The overall engagement of faculty in teaching, performing research with undergraduates—as discussed next—and advising undergraduates has led to two faculty members receiving the single university-wide Outstanding Faculty Award as selected by the entire student body, one receiving it in 2009 and the other in 2010. Additionally, the student body also selected the department to receive the Department of the Year Award in 2010. In addition to these student-selected awards, one faculty member was selected by honors students as the Five Star Faculty Award winner, which is only given to one faculty member each year. That faculty member also received the Sherrill Creative Teaching Award from the University of Arizona Foundation for demonstrating a long-standing commitment to excellence in educating undergraduate students.

In addition to teaching well, the department's faculty members have consistently made a strong commitment to engag-

TABLE 1
Department of Chemical Engineering Faculty

Faculty	Ph.D. Institution	Research Areas
Bob Arnold	Cal. Tech.	bioremediation, microbial catalysis
Jim Baygents (Interim Assoc. Dean for Academic Affairs, Engineering)	Princeton	transport and interfacial phenomena
Paul Blowers	Univ. of Illinois at Urbana-Champaign	sustainability analyses, kinetic and molecular predictions
Wendell Ela	Stanford	particle-particle interactions, remediation of contaminated water
Jim Farrell	Stanford	adsorption in mesoporous materials, electrochemistry
Jim Field	Wageningen University (The Netherlands)	anaerobic bioconversion of pollutants
Don Gervasio	Case Western Reserve University	electrochemistry, solar power
Roberto Guzman	North Carolina State University	protein and metal ion separation, polymer and surface chemistry for environmental/biotech. applications
Anthony Muscat	Stanford	atomic scale engineering of surfaces, semiconductor chemistries
Kim Ogden	University of Colorado	bioremediation and biotechnology
Ara Philipossian	Tufts University	chemical mechanical planarization, electroplating chemicals, dielectrics
Eduardo Sáez	University of California at Davis	transport phenomena, emerging contaminants
Glenn Schrader (Associate Dean of Research, Engineering)	University of Wisconsin	catalysis, environmental sustainability, thin films, kinetics
Farhang Shadman (Director of SRC/SEMATECH Engineering Research Center for Env. Benign Semiconductor Manufacturing)	UC Berkeley	semiconductor manufacturing, environmental contamination control
Reyes Sierra	Wageningen University (The Netherlands)	biological wastewater treatment, bioremediation, nanotoxicity
Shane Snyder	Michigan State University	emerging water contamination and remediation
Armin Sorooshian	Cal Tech	atmospheric chemistry and physics, climate change, aerosols



Mosaic of mentors:
The many faces of the University of Arizona's chemical and environmental engineering faculty:
Top row: Bob Arnold, Kim Ogden, Jim Farrell, Eduardo Sáez, Farhang Shadman.
Second row: Armin Sorooshian, Reyes Sierra, Wendell Ela, Jim Baygents, Ara Philipossian.
Third row: Paul Blowers, Greg Ogden, Jim Field, Roberto Guzman, Anthony Muscat.
Bottom row: Glenn Schrader, Shane Snyder, Don Gervasio.

ing undergraduate students in research. Students do research either as volunteers, for independent study that can be applied to their degree, or for pay, often through additional funds provided by the Undergraduate Biology Research Program or the NASA Space Grant Program on our campus. In addition to performing research within the department, students also routinely work in systems and industrial engineering, electrical engineering, biomedical engineering, optical sciences, chemistry, or medical research laboratories outside the department due to the campus's support for undergraduate involvement in research. Undergraduate researchers are often included as co-authors on scientific peer-reviewed papers. In the past six years, 31 peer-reviewed publications from faculty members have been published with undergraduate students as co-authors—demonstrating a high level of engagement of undergraduate students in the research enterprise.

Students are encouraged to not only develop their professional resumes through research, but to also pursue internships with companies. While intern-

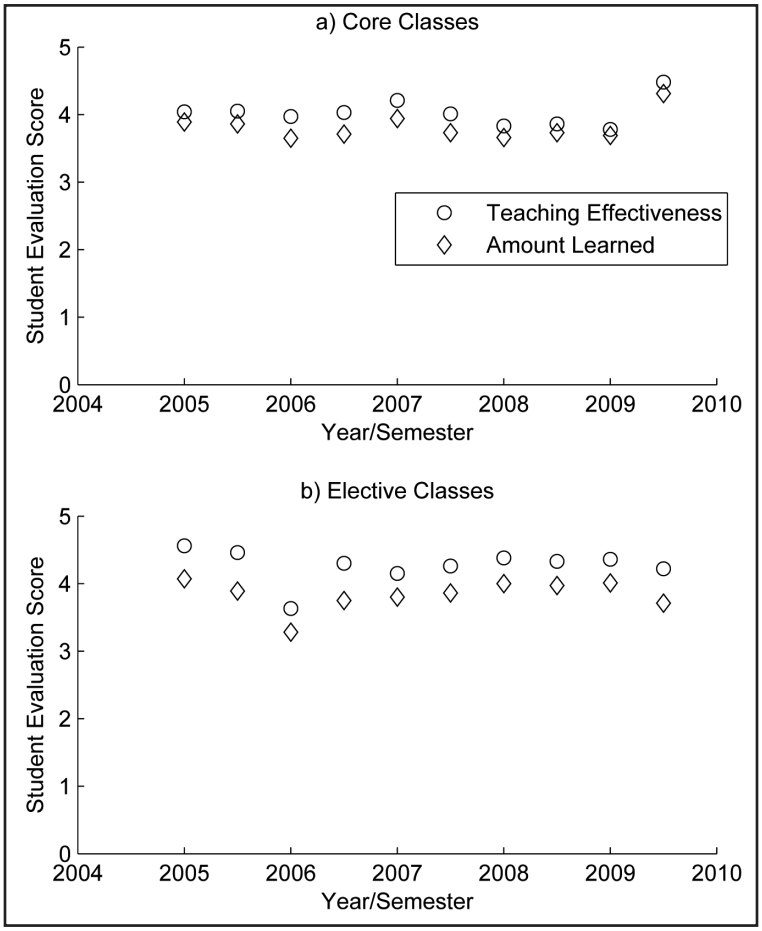


Figure 1. *Average faculty teaching course evaluation scores on a five-point scale as reported by students at the end of each semester.*

ships are not required, a large number of students have been able to secure paid work.

The third leg of student success is built on service and leadership activities. In the recent past, chemical engineering students have held officer positions in the College's Tau Beta Pi Honor Society, the Engineering Student Council, the Society of Women Engineers, and Engineers Without Borders. In addition to these clubs that are closely related to the discipline, students from the department have also founded the American Tae Kwon Do, Arizona Marathon Runners, Arizona Boxing, and Arizona Jugglers clubs. Students remain engaged in a wide variety of activities, even on top of their academic workload; one student even finished in sixth place at the PAC 10 championships for track and field. Another student was ranked number one in the world in hand-to-hand combat in tae kwon do, while a third qualified for the national table tennis championships.

Students from the department win many awards at both the local and national levels. Each year, the College of Engineering recognizes one senior as the Most Outstanding College Senior and each of the 18 degree programs can nominate one graduating senior. Of these last five selections, a chemical engineering student was chosen three times for this honor. The university gives three awards each year for outstanding service leadership to all graduating seniors, and two students from chemical engineering were selected in the last nine years. The University Honors College names between 10 and 12 Pillars of Excellence each year; of the 32 named in the three years of the program, five have been chemical engineering graduating seniors. At the national level, from AIChE, two students have won National Minority scholarships, three have been selected for the Donald Othmer Award, and one received the John McKetta Award. Two students were selected as Tau Beta Pi scholars and one was named Tau Beta Pi Laureate as the best engineering student in the country. The Udall Scholarship is a national award given to approximately 80 students nationwide each year, and students must be engaged in environmental or tribal issues to be selected. Two of our students have been selected in the last five years, and one of those students went on to have a Fulbright Fellowship and is now an NSF fellow in graduate school. In the most recent graduating class, one student earned second place from the National Society of Black Engineers at an open oral competition, while another student was selected by the Society of Hispanic Professional Engineers as the Most Valuable Player for Design.

Not surprisingly, with the strong support from the department and college to become involved in research, and the encouragement to obtain internships and to develop leadership and engagement activities, placement of graduates has been strong each year. In almost every year, only two or three students have not signed a commitment by the day of graduation.

Companies that routinely recruit multiple graduates from our program include ExxonMobil, Intel, Proctor & Gamble, Raytheon Missile Systems, Freeport MacMoRan (a mining company), Gore (a biotechnology company), and Valero Oil. Environmental consulting companies take advantage of the strong environmental presence and hire students as well, with students going to Malcolm Pirnie, Brown and Caldwell, and CH2M Hill in recent years. Due to the broad emphasis on fundamentals and applicability to any industry, our students are able to work for a broad spectrum of companies, allowing flexibility in job searches while industries wax and wane in their demand for new B.S. graduates.

Approximately 30-35% of each graduating class goes to graduate school. Currently, students are in graduate school in chemical engineering at UT Austin (five students), Berkeley (three), Cal Tech (three), University of Illinois at Urbana-Champaign (five), and Stanford (one), among others. Again,

Students participate in a classroom activity. Interactions with students foster engagement in learning.

the broad training and emphasis on flexible options allows our students to move into other fields if they choose not to go to chemical engineering programs. Four students have successfully been admitted to medical school programs, with one of them earning a position in an M.D./ChE Ph.D. program. One student has gone on to receive a Ph.D. in pharmacy, while another received a law degree from Duke University. Several students have gone on to biomedical graduate-degree programs, while one has gone on to a Ph.D. program in dairy science at the University of Wisconsin and another entered Oxford University for an M.S. in archeology.

THE GRADUATE PROGRAMS

The department maintains two separate graduate-degree programs, one in chemical engineering and one in environmental engineering, with both programs offering both M.S. and Ph.D. research-centered programs. Both programs also have a coursework-only M.S. option. There are about 65 graduate students in residence at any given time, supported by their research advisors.

Master's degree candidates from environmental engineering are generally hired by environmental consulting firms and utility companies across the United States. There are relatively few M.S. chemical engineering graduate students, and those that pass through the program often go on to graduate school at other institutions; one was at the University of Illinois at Urbana-Champaign and just completed a Ph.D., and the other is in the fourth year of an M.D./Ph.D. program at the University of Boston. Ph.D. students from both programs primarily go to industrial positions or positions at utility companies after graduation, although several alumni are faculty members at other institutions, including North Dakota State University, Stanford University, The University of Utah, and San Francisco de Quito University in Ecuador.

Graduate students are encouraged to not only do well academically and in their research areas, but to also develop themselves. Departmental seminar series generate research ideas from graduate students during coffee-hour presentations on their research. In addition, many students participate in intramural and recreational activities within the department and across the campus. A large number of students also start families while in the program and balance work with their outside lives. This may be encouraged by the holistic approach of the faculty in maintaining similar balances in their personal lives, as discussed later.

Strong connections are maintained with alumni from all undergraduate and graduate programs. This has facilitated the sharing of job openings with alumni and graduating seniors as they search for jobs. These connections and communication efforts have also enhanced recruiting of interns from the program as employers observe the developmental efforts the faculty make to get students involved and engaged in becoming strong professionals through research, leadership, and internships.

Research areas in the graduate programs include, but are not limited to, chemical engineering solutions to environmental problems, including water and wastewater treatment, (bio)remediation, and environmental aspects of semiconductor manufacturing. Other areas of emphasis are nanofabrication, biotechnology, biofuels, molecular-scale simulation of chemical interactions, rheology, electrochemistry, and catalysis.

LIFE BALANCE AND HOLISTIC APPROACHES FOR SUCCESS

Faculty are also leaders in and around the local community and the country. One faculty member is currently secretary of the National AIChE organization. Several faculty members have served on editorial boards for top journals or served on national oversight committees for technology development. At the local level, two different faculty members have participated in an event that brings together faculty from campus, employees at local technology-based companies, and volunteers to host 6,000 middle-school-aged children at the Tucson Convention Center to do hands-on science and engineering events over a three-day period. At the university and college level, at least seven faculty at any given time are in visible leadership positions.

For over a decade, faculty members have demonstrated the ability to balance their professional demands in teaching, research, and service, with their personal lives—providing a strong model to students at all levels. Many faculty children are often present in the building during working hours, often with a gate at the door to keep toddlers in. Some faculty lecture with their children unobtrusively present in the classroom—one did so while wearing a baby carrier for a toddler, and others while having their children draw quietly or work on their own tasks. Being engaged as a faculty member does not mean having to sacrifice family interactions.

The clear engagement of faculty in many activities at high levels encourages undergraduate and graduate students to challenge themselves while maintaining good life balances. With the addition of two new faculty members in 2010 in research areas that complement existing departmental strengths, while also maintaining a balance between professional and personal lives, the future promises to hold continued strengthening of the department and larger successes. ❐

Founding father: Don White, the founder and first head of the department.