ChE at Tennessee Technological University

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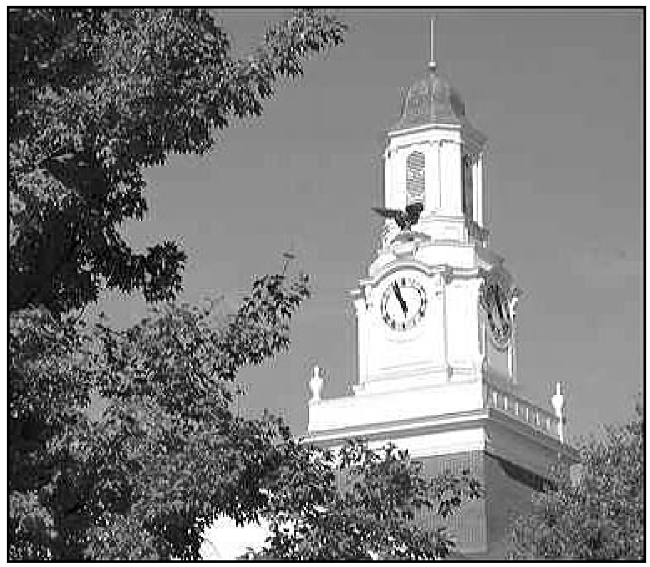
WITH FACULTY AND STAFF

Tennessee Technological University (Tennessee Tech) began its life as Dixie College in 1909, with a few small but elegant Georgian buildings on 7th Street and Dixie Avenue in Cookeville, Tennessee. The tiny, then-private college* evolved into Tennessee's only technological university with a strong engineering, science, business, and education emphasis. By the end of the 1940s the seed for what would eventually become chemical engineering was planted within the Department of Chemistry, but the sapling soon withered and became dormant for another two and a half decades. In 1966, a young man named **John C. McGee**, a Ph.D. from North Carolina State University, was hired. Kindled by the presence of a growing chemical industry in Tennessee, McGee and a colleague from the already established Mechanical Engineering Department officially became the Chemical Engineering Department and McGee served as its first departmental chairperson. Not long after, **W.D. (Denny) Holland** (Ph.D., Georgia Tech) was hired, followed by **David W. Yarbrough** (Ph.D., Georgia Tech) and **Clayton P. Kerr** (Ph.D., Louisiana State University). These four men, young and energetic, would build the department from grass fields and empty rooms, lay the foundation for a strong unit-operations tradition, construct a lasting laboratory infrastructure, cultivate the master's program, embrace the college-level Ph.D. when introduced in 1971, pioneer computational techniques that were budding ideas at the time—and become respected and dedicated educators, researchers, and friends for the next three-plus decades, thus sowing the seeds that would grow into the present-day Department of Chemical Engineering.

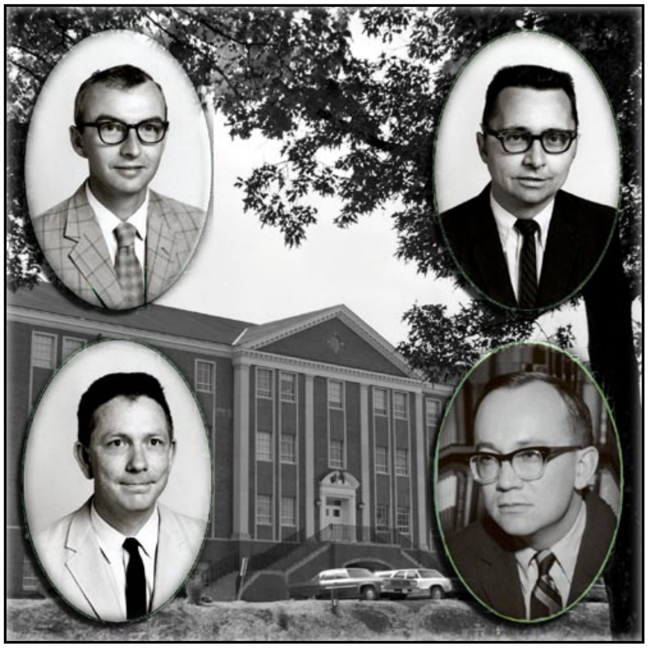
While Professors McGee, Holland, Yarbrough, and Kerr would, from time to time, be joined by other faculty, they alone would remain for a life's career at Tennessee Tech.



The clock tower at Derryberry Hall.

These historical notes are brief yet important. The present faculty acknowledges and owes much of the department's ongoing success to the foundation that Professors Emeriti McGee, Holland, Yarbrough, and Kerr established. In 1999, both McGee and Holland retired, followed by Yarbrough and Kerr in 2001 and 2002, respectively. Since then, the department's faculty has been re-created, ushering in a new wave of excitement and productivity. Much as the department's founders laid the cornerstones and built a tradition and legacy, the present faculty has initiated a renaissance: introducing new research thrusts, modernizing both the undergraduate and graduate curricula in content and pedagogy, and stepping forward in service to regional outreach and their respective professional communities. The remainder of this article deals with the present, and to some extent, a vision for the future.

* *Dixie College, formally Dixie University, was founded by the Church of Christ in 1909.*



Yearbook photos (ca. 1976) of (clockwise from upper left) early faculty W. Denny Holland, John C. McGee, Clayton P. Kerr, and David W. Yarbrough, superimposed on a picture of Prescott Hall, home of the Department of Chemical Engineering since 1971.

PLAYING LIKE A TEAM—INSIGHTS FROM OUR VISITING SPEAKERS

Each academic term the department hosts what has become a model research seminar series within the university, bringing in eight to 10 regional and national speakers. If you have been one of our speakers, you know that this will not be a day of rest for you. A full day of interaction with the students and faculty will be carefully planned and integrated with your seminar and, in the end, you will likely know who we are and we will know something about you. Consistently and almost universally, at the end of the day our guests tell us that the single most striking characteristic of our department is how the faculty clearly demonstrates collegiality, teamwork, and a sense of scholarly community.

This is a posture that we cultivate and strive to perfect. **Pedro Arce**, the department's chairperson, is a well-known educator, having developed several strategies for teaching and learning including "The Coach Model.[1, 2]" It is no coincidence that we view the department as a team. Arce mentors the junior faculty, gives them opportunity to grow as team members, listens to his players, is sensitive to the environment of the game and, in the end, lets his team play. Formally, one might call our management structure distributed and unoriginal.† Faculty empowerment is the factor that changes the equation.

Our faculty members represent the department and carry their own authority as well as the confidence of the chairperson and each other. Each faculty member is empowered to "play his/her position" and to "pass or shoot" when he or she sees the opportunity.

A team has many elements; not all are on the field. Our team has two additional individuals without whom the game could not be played: **Rebecca (Becky) Asher,** our departmental office coordinator, and **Perry Melton**, our laboratory and machine shop technician. While Asher is holding the department together by responding to the many requests of the faculty and day-to-day student needs, Melton is keeping the unit operations running and working with students to build equipment that they design, as well as helping the faculty and graduate students with research labs.

EDUCATIONAL OBJECTIVES—INSIGHTS FROM OUR CONSTITUENTS

As part of our recent Southern Association of Colleges and Schools (SACS) accreditation, Tennessee Tech has a newly established Quality Enhancement Program (QEP) and, accordingly, a QEP Committee.‡ This committee surveyed the constituency of the university—our students, alumni, employers of our students, and the faculty—and found that unilaterally, "what really counts" are critical thinking skills and the ability to solve "real-world problems.[3]" When it came time to review our departmental Program Educational Objectives (PEOs) it was simple: We would integrate critical thinking and real-world problem solving in some way, and we would write PEOs that were timeless.

The result is our present statement of PEOs that are our driving force and motivation:

Within roughly five to seven years our graduate population will collectively exhibit the following traits:

- *be critical thinkers*
- *be real-world problem solvers*
- *have continued their formal education*
- *be working at the frontiers in chemical engineering*

In addition to real-world problem solving and critical thinking, we have chosen to explicitly call for the continuation of formal education and working at the frontiers in chemical engineering. These two objectives complete the characteristics of our program: an environment that empowers students to take responsibility for their own learning (lifelong learning) wherein research (the frontier) is highly integrated with, and pushes the boundaries of, undergraduate education—making it compatible and forming a continuum with graduate studies.

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† *Technically, the department uses a transformational-based managerial structure with a strong team-based component.*

‡ *Several ChE faculty members have received seed grants from the University-wide effort to integrate critical thinking and real-world problem solving activities across campus.*

THE FACULTY—INSIGHTS FROM OUR AMBIDEXTROUS SCHOLARS

If you ask any one of us what characterizes the departmental faculty best, we will tell you it is balance. We strive to create an effective balance between research and education so that students are exposed to an environment that maximizes their learning, and we do it across the department as a pervasive way of being. Such balance between excellence in teaching and research is taken seriously, and our faculty members demonstrate this characteristic by being active and visible in both arenas—endeavoring to integrate research and education in unique ways and to create new paradigms for student achievement. Professor **Donald Visco**, for example, has received both a Presidential Early Career Award for Scientists and Engineers (PECASE) for his research on solving inverse design problems, and the American Society for Engineering Education ChE Division's Ray W. Fahien Award for his vision and contribution to chemical engineering education.

So, what are the characteristics that lead to a balanced faculty member? The answer, apparently, is that many boundary conditions can lead to similar outcomes.

Chairperson and Professor Pedro Arce was born in Argentina and received his undergraduate education in his homeland's practice-oriented engineering system at the Universidad Nacional del Litoral (Santa Fe). He started his transformation as a member of the prestigious National Council of Research (CONICET) at one of the leading research and development institutes (INTEC) of Argentina before coming to the United States in 1983. Arce's transformation was completed by the great research and education scholars at Purdue University, fusing—as his mentors have—the desire to achieve the perfect balance between the two ideologies.

Professor Biernacki is the undergraduate product of Case Western Reserve University's research-driven program of the late '70s and the more applied Doctor of Engineering (DRE) program at Cleveland State University. He has 15 years of industrial experience, yet retains a fundamental approach to his research and says that "Teaching is a performance, and I simply love the audience, the stage, and the script."

Assistant Professor **Ileana Carpen**, who is finishing up her third year at Tennessee Tech, represents a great milestone for the department. With a B.S. from Stanford, a Ph.D. from Caltech, and a post-doctoral appointment at the University of Twente, this faculty member demonstrates that it is possible to recruit the finest academically trained individuals into our program because it places an equal emphasis on both education and scholarly research.

Assistant Professor **Holly Stretz** is the rarest of all—a high school teacher turned Ph.D. chemical engineer. Stretz has a

TABLE 1
Various Awards and Honors of the Faculty

Educational Scholarship and Related Service	
2008	Outstanding Teaching Award, ASEE Southeastern Section
2008, 2007	Outstanding Faculty Award for Teaching, Tennessee Tech
2008, 2007, 2006	Tennessee Tech College of Engineering Brown-Henderson Award, for outstanding Engineering faculty
2008,[9] 2006[12]	ASEE, Southeast Section, Thomas C. Evans Award, for best paper
2007	Outstanding Campus Representative, Zone 2, ASEE
2007	Outstanding Campus Representative ASEE Southeastern Section
2006[12]	ASEE Corcoran Award, for best paper
2006	Quality Enhancement Program Award for Innovative Instruction, Tennessee Tech
2006[13]	Annals of Research in Engineering Education, invited feature article
2006	Ray E. Fahien Award, ASEE
2004	Outstanding Campus Representative, 2nd Place, ASEE Southeastern Section
2001	ASEE Membership Award, ASEE Southeastern Section
Research Scholarship and Related Service	
2007	Distinguished Faculty Fellow, Tennessee Tech
2007	American Concrete Institute (ACI), Fellow
2007	ACerS (American Ceramic Society) Profiles in Excellence
2007	Oronzio De Nora Postdoctoral Fellowship, The Electrochemical Society
2006	Invited Visiting Professor, University of Wollongong, Australia
2006	Oronzio De Nora Young Author Award, International Society of Electrochemistry
2006, 2005, 2002	Leighton E. Sissom Innovation and Creativity Award, Tennessee Tech
2006, 2005	College of Engineering Dean's Advisory Board Award for Excellence
2005	New Faculty Research Award (1st Place), ASEE Southeastern Section
2004	Presidential Early Career Award for Scientists and Engineers, DOE
2004	NNSA DOE-DP Early Career Scientist and Engineer Award, DOE
2003	New Faculty Research Award (2nd Place), ASEE Southeastern Section
2003	Outstanding Faculty Award for Professional Service, Tennessee Tech
2002[14]	Sigma Xi Research Award, Tennessee Tech
2002,[15] 2000[16]	Kinslow Engineering Research Award, for best paper, Tennessee Tech

The faculty and staff of the Department of Chemical Engineering, from left to right, front row: Ileana Carpen, Rebecca Asher, and Holly Stretz; back row: Don Visco, Vijay Boovaragavan, Perry Melton, Venkat Subramanian, Pedro Arce, Joe Biernacki, and Mario Oyanader.

B.S. degree in chemistry from Texas A&M, worked in the polymers and semiconductor industries for five years, taught high school in the public school system, and studied in the world-renowned research laboratories of Don Paul[4] at the University of Texas, Austin.

Associate Professor **Venkat Subramanian** came to the United States with an undergraduate degree from India's distinguished Central Electrochemical Research Institute, to join Ralph White's group at the University of South Carolina. Subramanian merges his passion for applied mathematics with electrochemistry and likely has one of the most productive research groups on campus. He is presently digesting his work into a text for undergraduate and graduate students.

Professor Visco, mentioned previously, studied at the University at Buffalo, State University of New York. He tutored as an undergraduate student, an experience that he reports would ultimately shape his career. Visco had an extended industrial internship, served in the U.S. Navy, and is now recognized as one of the nation's finest young researchers in the field of inverse design, yet found time to be the department's undergraduate program coordinator for the past four years—weaving the fabric of our curriculum and creating new and exciting opportunities in undergraduate chemical and biomolecular engineering.

The department is also home to two other faculty members. Adjunct Assistant Professor **Mario Oyanader** (originally from Chile) is both an outstanding researcher and rising young educator. Trained in Arce's own group at Florida State University (where Arce taught prior to becoming our chair), Oyanader has the characteristics of both a scholar and an educator who is "all about critical thinking." He is leading the renaissance effort in process design and helping to re-cast the Unit Operations Laboratory role within the new integrated curriculum. Research Assistant Professor **Vijayasekaran (Vijay) Boovaragavan** joined Subramanian's group as a post-doctoral researcher and was recently hired to his current position. He received two international competitive distinctions for his research while at Tennessee Tech and presently co-teaches our Operations course.

The ChE Department at Tennessee Tech offers another answer to the old question, "Research or education?" Scholarship in both is achievable, although a balance must be accepted. Collectively, the Tennessee Tech chemical engineering faculty have earned 35 awards and distinctions since 2000 (see Table 1). Many of these are top Tennessee Tech honors, others are national recognitions, and yet others are international distinctions—the sum of which paint a picture of balance, combining elements of research scholarship and excellence in education. This does not happen by chance; emphasis must be placed on maintaining a rational balance. Furthermore, our experience is that an undergraduate program's excellence is enhanced by strengthening the graduate program. The adage "one cannot have a strong graduate program if too much attention is paid to undergraduate education" is simply contrary to the Tennessee Tech experience.

STUDENT-CENTERED LEARNING—INSIGHTS FROM HOW OUR STUDENTS LEARN

It is well accepted that students learn best by doing,[5] and while there are a range of learning styles, most education researchers would agree that active participation is key to retention and ultimate internalization of learned information.[6] Furthermore, most would also agree that educators must relinquish their tradition of teacher-centered control and place control in the hands of the students who must be empowered to learn,[7] *i.e.*, we must provide student-centered learning environments.[8] These pedagogical principles guide the many changes that we are presently implementing across the curriculum.

Active learning is one of several guiding principles being

The 2005 National Champion AIChE Chem-E-Car Team from Tennessee Tech, from left to right: Jonathan Phillips, Braxton Sluder, Jason Miller, Regan Chandler, Robert Phillips, Jennifer Pascal, and Haley Hunter.

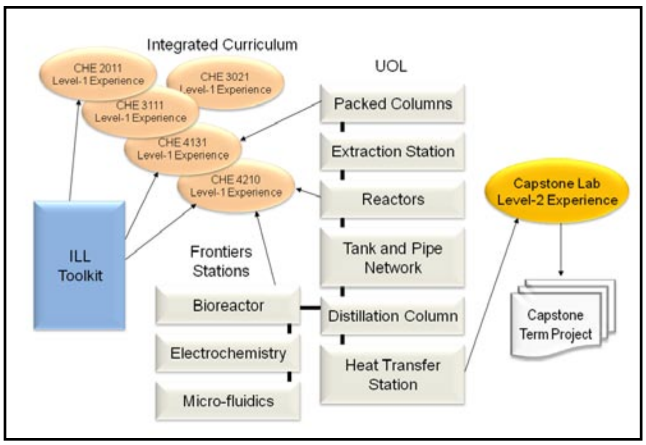

Figure 1. *The integrated lab-lecture (ILL) concept.*

advocated at Tennessee Tech on a universitywide basis. The Department of Chemical Engineering, however, has adopted active and collaborative (team-based) learning at large, and all of us are using some form of these approaches in our classes. The most ambitious of these efforts is growing out of our laboratory-and-lecture integration initiative. Our departmental founders established and passed on what we refer to as a "laboratory-oriented tradition." Four laboratory courses, totaling five credit hours, were required up until 2006 when the one-hour sophomore lab, the two-hour junior lab, and the one-hour first-semester senior lab were integrated with lecture courses across the curriculum. The remaining one-hour, second-semester senior lab was preserved for what is now called Capstone Lab. This bold move was met with some skepticism when first introduced; however, the extraordinary effort of the faculty to embrace this initiative has shaped and defined this concept in unexpected ways.

Motivated by the observation that students are unable to independently synthesize theory, computation practices, and the "real world," Biernacki proposed to adopt the lab-integration concept across the entire ChE curriculum in 2005.[§] Having pioneered small-scale labs and demonstrations as a regular part of some of their courses already (*e.g.*, courses on momentum and heat transfer, reaction engineering, thermodynamics, and process controls), the faculty team agreed that it could be done on a larger, curriculumwide scale. Thanks to the energetic leadership of Undergraduate Program Coordinator (2003-2008) Visco, official integrated labs are now part of six courses: Introduction to Mass Balances, all three transfer science courses, Chemical Kinetics, and Solution Thermodynamics/Separations. Newly named Curriculum Coordinator Stretz is working diligently with Oyanader and other faculty to re-create the role of the unit operations laboratory (UOL) within the new curriculum. Figure 1 illustrates the concept. Here, Level 1 experiences are related to our integrated labs. These integrated activities draw from a variety of physical resources including a growing lab tool-kit, the existing UOL, and New Frontiers chemical engineering stations. By the time students reach the Capstone experience (Level 2), they have numerous examples of how theory, computation, and observation (experimentation) work together, thus they are prepared to transition to a more independent, open-ended capstone experience.

One final note is that the integrated lab and lecture is not intended to be a course with a lab section (*i.e.*, a lecture with a lab). The single most important outcome of the lab-lecture integration is to break down the barriers between theory, computational practices, and the real-world. In Arce's view,[7] "Traditional lectures give way to integrated environments with a seamless transition from class to lab where the student is in the learning driver's seat." The approach effectively uses these three key elements of engineering education (classroom, simulation, and lab activities) to create a continuum that is seamlessly woven together, each providing input for validation of the other, and all working together. Certainly, some individuals are gifted experimentalists and others, theoreticians, yet the broader general education of the undergraduate must include a continuum that explores the relationship between concepts (theory), calculations (the computer), and the behavior of real things (the real world).

THE STUDENT CONTINUUM, RESEARCH AND EDUCATION—INSIGHTS FROM LESSONS IN SCALING

Arce was recently a recipient of the 2008 ASEE-SE Section's Thomas C. Evans Award for best paper published in engineering education during 2007. Arce is the only three-time winner of this prestigious award, this time sharing the honor with two co-authors, departmental adjunct faculty member Mario Oyanader, and Steven Whitaker of University of California at Davis, for their paper entitled, "The Catalytic Pellet: A Rich Prototype for Up-Scaling.[9]" In this paper, Arce, Oyanader, and Whitaker explain that the traditional chemical engineering curriculum and, for that matter, the traditional engineering curriculum, attempts to teach design—a study in scaling, if you will—in the final year of the program, thus creating a sort of "step function" in design content of the traditional curriculum. This approach effectively expects that students will synthesize everything they have learned in the past three years during two semesters, thereby transforming them into "engineers." This approach, the paper argues, has a long history but is fundamentally flawed. Many have advocated "design across the curriculum," and similar programs, with some success. The paper's concept is to *exploit* distributed laboratory courses and use real-world activities (*e.g.*, the experimental prototype[7, 10]), thereby introducing concepts of scale and effectively "scaling up" the knowledge of students as they move through the curriculum—instead of trying to accomplish the same all in one year. The approach introduces a progressive type of curriculum that will require new didactic materials (*e.g.*, textbooks, simulations) and a new vertical integration of the curriculum that, for Transport Phenomena, is already in place at Tennessee Tech.

We take the concept even further in the department and, in fact, view the student body, both graduate students and undergraduates, as a continuum in the lifelong-learning process. Barriers among student groups—juniors, seniors, master's degree-seeking graduate students, Ph.D.-seeking students, etc.—are considered obstacles to learning, growth, and scholarly productivity. While there are a number of effective tools that can be used to unify the student body, we feel that research is by far the most productive and learning-rich vehicle. Research not only promotes critical thinking and facilitates learning development, it also promotes the idea of a community of learners among undergraduates, graduates, postdoctoral students, and faculty. Although not every undergraduate will engage (formally) in research, we feel that research activities should be a ubiquitous "fluid" that permeates every classroom/lab and catalyzes as many elements of the curriculum as possible, facilitating student learning and critical thinking. To this end we have initiated a number of integrating elements to our curriculum, and we advocate that students engage in them along with university-led research activities.

While there are numerous aspects of the program that emphasize integration, several merit special mention in addition to the lab-lecture integration:

1) *the Distinction in the Major (DITM) option, a formalized and intensive undergraduate research track that leads to a written and oral thesis defense;*
2) *the Research Seminar Series,[11] briefly mentioned above;*
3) *the Chemical Engineering Graduate Research Association (CEGRA), a student-governed organization that serves the needs of the graduate student body.*

We feel these aspects are critical to the departmental success. In combination with pedagogy that empowers students to take charge of their own learning, we hope these aspects will create a culture of scholarship emphasizing critical thinking, problem solving, lifelong learning, and extending the frontiers of knowledge. Our faculty, although relatively small compared to others in the Southeast, is able to offer Tennessee Tech's students a cross-section of frontier areas in which to work. Arce and Oyanader are interested in electric field-based processing, *e.g.*, electrokinetic hydrodynamics, corona discharge processing. Biernacki's main research focus is experimental reaction kinetics, most recently emphasizing portland cement-based materials. Carpen's interests focus on complex fluids (the rheology of colloidal suspensions and polymer composites) and on biomedical systems (tumor growth and tissue engineering). Stretz's efforts focus on the experimental characterization of nano-particle polymer composite behavior, and nano-particle ordering and high temperature behavior of similar materials. Subramanian's computational research brings together electrochemistry, complex transport modeling, applied mathematics, and computer programming for the development of ultra-efficient algorithms for real-time batteries and fuel cell performance prediction, system optimization, and control. Subramanian is joined by Boovaragavan, who is presently funded by a prestigious international grant award from the The Electrochemical Society. Finally, Visco's work involves a spectrum of computational thermochemistry and molecular design initiatives as well as laboratory research on phase equilibrium. Collectively the faculty are or have been funded by numerous government and private-sector organizations working closely with Tennessee Tech's three state-funded research centers, and have many ongoing or prior research collaborations. Such collaborations enhance opportunities for our students and faculty to work with leading scholars amid some of the finest research

§ *The concept parallels the "High Performance Learning Environment (HiPeLE)" developed by Arce and collaborators, 2004, CEE.*

infrastructure in the world.

The outcomes are remarkable. In the last five years our undergraduates have amassed top honors in numerous competitions:

- *Our Chem-E-Car team has consistently been in the top tier and has pioneered first-of-a-kind competition vehicles, having established the current national record and first place at the national competition in 2005 and second at the AIChE Southeast Regional Meeting this year (2008) with one of the first Bio-Cars to be entered in the competition.*
- *Collectively, our students have received top paper and poster awards at regional and national competitions.*
- *In 2006,* **Jennifer Pascal** *(one of our first DITM graduates and a current Ph.D. student) received the AIChE Othmer Award, and* **Hope Sedrick** *was selected as one of 10 students to receive a NIST SURF internship.*

Recent graduate students have performed similarly well.

- *Ph.D. student* **Vinten Diwakar** *received The Electrochemical Society's Industrial Electrolysis and Electrochemical Engineering Division Student Achievement award in 2006 for his research on battery and fuel cell modeling, (Subramanian, his Ph.D. advisor, was also a recipient of this prestigious award as a student).*
- *Ph.D. student* **Pravin Kanan** *was selected for the BASF International Summer Course in Bohn, Germany, in recognition of his research on polystyrene foam thermal decomposition.*
- *Master's student* **John M. Richardson** *received an NSF Graduate Research Fellowship in 2002 for his research on nano-pore structure of hydrated portland cement, a first for Tennessee Tech.*
- *In addition, our B.S. and M.S. graduates are being hired by leading companies. Recent Ph.D. graduate* **Dr. Baburao** *was highly sought by design companies and* **Dr. Swaminathan** *is currently a post-doctoral research associate at the Technical University of Denmark.*

The list of similar awards and achievements is long, but these illustrate the excitement and success among our students and, we believe, the result that is achievable with a program that focuses on scholarship in both education and research through integration rather than separation.

ABOUT TOMORROW—INSIGHTS FROM OUR VISION OF THE FUTURE

It seems appropriate to dream and to speculate just a bit at this point in the department's story. We recently revised our vision statement as well as our PEOs, and after considerable debate over two words—"will be"—we were convinced by our Board of Advisors to phrase our vision statement in the present tense and to use the word "is." Thus, our official Vision now reads as follows:

The Department of Chemical Engineering **is** *a recognized leader in chemical engineering education through excellence in teaching, research, and service.*

This statement "is" a vision of the future for us—simple, yet a bold supposition that we believe "will be." The path from here to there for us is clear: (1) continue to respect and build upon the foundations of our legacy; (2) develop and grow a faculty that "plays like a team;" (3) have clearly stated educational objectives that are simple and timeless; (4) maintain a balance between research scholarship and education, and strive to excel in both; (5) fervently maintain a student-centered learning environment; and (6) integrate the student body, integrate research with education, and do not let "size effects" influence the *scale* of our productivity.

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