

Brigham
Young
University,
Provo, Utah.
Credit:
BYU Photo.



Chemical Engineering at ... Brigham Young University

RANDY S. LEWIS AND L. DOUGLAS SMOOT

Brigham Young University (BYU), located in Provo, Utah, was founded as Brigham Young Academy (BYA) on Oct. 16, 1875. Karl G. Maeser, an educator from Germany, was the first principal and was charged by Brigham Young “to remember that you ought not to teach even the alphabet or the multiplication tables without the Spirit of God.”^[1] True to the original charge, BYU seeks to develop students of faith, intellect, and character who have the skills and the desire to continue learning and to serve others throughout their lives. Initially, there was a single academic department, and all took courses in arithmetic, algebra, geom-

etry, surveying, drafting, chemistry, and physics. From that early beginning, drawing, mechanical arts, surveying, and eventually industrial arts were offered during the first half of the twentieth century as BYA grew from its starting class of 29 students in 1876 to 4,500 students in 1950.^[2] Sadly, the first academy building burned to the ground in 1884, leaving the fledgling academy destitute. However, through great sacrifices of the Board of Trustees, including Abraham O. Smoot, first president of the board^[3] and great grandfather of chemical engineering professor L. Douglas Smoot (see below), BYA became BYU in 1903.^[2]

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BYU is sponsored by the Church of Jesus Christ of Latter-day Saints (LDS Church) and is part of a large church-sponsored educational system that includes BYU-Hawaii in Laie, Hawaii, and BYU-Idaho in Rexburg, Idaho. BYU also has two satellite campuses, one in Salt Lake City and one in Jerusalem. BYU is the largest of the campuses with an enrollment of 33,363 daytime students from all 50 states and 105 countries, with 53% male students and 47% female students. Approximately 65% of BYU students speak a second language, with 126 languages spoken on campus. Based on full-time undergraduate enrollments and excluding online enrollments, BYU is the largest religious university and the largest non-profit private university in the United States.^[4]

The goal of a BYU education is to be spiritually strengthening, intellectually enlarging, and character building—leading graduates to life-long learning and service.^[5] Although the primary focus is on undergraduate education associated with 180 undergraduate majors, BYU offers 62 M.S. and 26 Ph.D. programs within 11 colleges to provide a strong learning environment. A major emphasis is placed on undergraduate mentored research to foster educational learning in tandem with traditional classroom instruction. The Ira A. Fulton College of Engineering and Technology has more than 4,000 students majoring in chemical, civil & environmental, electrical & computer, and mechanical engineering, as well as construction management, facilities & property management, industrial design, information technology, manufacturing engineering technology, and technology engineering education.

BEGINNING OF CHEMICAL ENGINEERING^[6]

In 1951, discussions to organize a new engineering curriculum were first seriously considered with the appointment of Ernest L. Wilkinson as BYU president. With President Wilkinson's urging of Dr. Harvey Fletcher (grandfather of current ChE professor Tom Fletcher) to come to BYU as director of research in 1952, the foundations of engineering were cast in concrete. Prior to coming, Harvey worked at Bell Telephone Laboratories as a prominent researcher in acoustical science and as a professor of electrical engineering at Columbia University. Early discussions on the projected high cost of engineering were discouraging but the concept of an "engineering science" program was favorable with more emphasis on science than traditional engineering. This resulted in less need for expensive engineering laboratories.



The Harvey Fletcher Building. The first engineering building at BYU. Credit: BYU Photo.

In 1952, the Board of Trustees approved the establishment of the Department of Engineering Sciences with Harvey Fletcher as chair. Six options were announced, including chemical (in the Department of Chemistry), civil, electrical, mechanical, geological (in the Department of Geology), and acoustical engineering sciences. Similar to today, there was some sentiment nationally for a five-year engineering bachelor's degree, so a five-year program was announced.^[7] At this time, there were no faculty members in the Department of Chemical Engineering. By 1953, 250 students had enrolled in engineering at BYU and the construction of the Harvey Fletcher Building to house the engineering programs was initiated. In 1954 the College of Physical and Engineering Sciences was established, and in 1957 the Chemistry Department was changed to the Chemistry and Chemical Engineering Department.^[8]

Chemistry Professor Angus Blackham taught the first chemical engineering course in stoichiometry. Dr. Billings B. Brown, the first chemical engineering faculty member to be hired and a recent graduate from the University of Washington, started at BYU during 1953 to help teach and organize the chemical engineering program in the Department of Chemistry.^[8] Because Dr. Brown had no official administrative appointment or title—since chemical engineering was not yet a department—he was listed as the chemical engineering program coordinator. Dr. Wendell Wiser came to BYU as the second chemical engineering faculty member in 1955. It was these two, together with chemistry faculty member Blackham, who taught the chemical engineering curriculum to the first graduating class in 1956.

In 1958, chemical engineering became its own department with Billings Brown, then an associate professor, as the department chair (although he went on leave one year later).

James J. Christensen, Bill J. Pope, and Dee H. Barker joined the faculty and by the end of the Fifties there were three faculty members, 110 students, and 46 alumni.^[8] Additionally, the department was housed in the new Fletcher building. However, the laboratory equipment was sparse, the program was unaccredited, and there was no significant research or research funding, although there was modest research involving combustion and reactions of hydrocarbons. At this time, most of the students were from Utah, California, and Utah's bordering states.

THE GROWTH OF CHEMICAL ENGINEERING

The Chemical Engineering Department received its first accreditation in 1961 as a 5-year program. The M.S. program was approved in 1962 and the doctoral program was approved in 1968, initiating strong research programs that enabled the pursuit of cutting-edge research while also strengthening the undergraduate educational experience through student mentoring. Average undergraduate enrollments grew rapidly from the low hundreds through the 1960s, to the low two hundreds in the 1970s, eventually reaching the low four hundreds in the 1980s before decreasing to the low three hundreds and stabilizing at this size through the '90s and early 2000s.

During this period, the faculty expanded to 12 members. In addition to the faculty members noted above, faculty hires through the first 50 years included L. Douglas Smoot (1960), Richard W. Hanks (1963), M. Duane Horton (1963), Dwight P. Clark (1964), Joseph M. Glassett (1966), Ralph L. Coates (1967), Vern C. Rogers (1969), Grant Wilson (1972), Calvin H. Bartholomew (1973), James F. Jackson (1974), John L. Oscarson (1974), Kenneth A. Solen (1976), Paul O. Hedman (1977), Merrill W. Beckstead (1977), B. Scott Brewster (1979), Douglas N. Bennion (1980), Philip J. Smith (1982), William C. Hecker (1982), Richard L. Rowley (1984), Ronald E. Terry (1987), William G. Pitt (1987), John N. Harb (1988), Thomas H. Fletcher (1991), W. Vincent Wilding (1994), and Larry L. Baxter (2000).

In 1972 the engineering and technology programs combined to form the new College of Engineering Sciences and Technology, which is now known as the Ira A. Fulton College of Engineering and Technology. It was at this time that the chemical engineering degree was changed from the five-year B.E.S. degree to a four-year B.S. degree. The Clyde Engineering Building was completed in 1973—a first-class engineering center of approximately 170,000 square feet. L. Douglas Smoot served as the dean of the College of Engineering and Technology from 1977 to 1994.

Research in the 1960s included coil heat transfer and solution thermodynamics, saline water solutions, and pulp-making. In 1965, Professor Tracy Hall, professor of chemistry, organized the High-Pressure Center. Hall held a joint appointment in chemical engineering for a time and worked with Bill Pope and Duane Horton in high-pressure research. It was Hall,

while at General Electric, who first synthesized industrial diamonds. Toward the end of the 1960s, combustion-related aerospace propulsion work was developing rapidly (Professors Coates and Smoot). James Christensen had teamed with Reed Izatt of chemistry to form the Center for Thermochemical Studies, which grew over the years into a major research effort at the university.

In the 1970s, research on combustion and gasification, solid propellants, catalysis, and bioengineering was initiated along with a significant expansion of research in thermophysical properties, diamond synthesis, and fluid mechanics. During the 1980s, research expanded into electrochemical systems, combustion modeling, molecular modeling, and some biomedical engineering. The Combustion Laboratory also became the Advanced Combustion Engineering Research Center (ACERC) based on a major NSF 11-year, \$20,000,000 grant supplemented by many participating U.S. companies. Nine of the faculty were involved in ACERC during this decade, in addition to BYU faculty members from mathematics, chemistry, and mechanical engineering and faculty members from the University of Utah. Research in the above areas continued into the 1990s. During this time, the Design Institute for Physical Properties (DIPPR) 801 database project was awarded to BYU chemical engineering (1998) with a major long-term contract.

THE CURRENT YEARS (2000-2017)

Chemical Engineering at BYU (<<https://chemicalengineering.byu.edu/>>) has come a long way since the beginnings in 1952. The program is strong and vibrant. During the last decade, student enrollments have grown significantly to more than 650 undergraduate students (approximately 25% female) and 50 graduate students. This growth has resulted in BYU's Chemical Engineering Department typically being in the top 20 U.S. programs based on number of undergraduates. The caliber of students entering the chemical engineering program is very high with an average ACT of 30.2 and an average high school GPA of 3.84. These statistics are slightly higher than the average of all students entering BYU (averages of 28.6 ACT and 3.81 GPA).

The demographics of chemical engineering students show a unique blend of characteristics. In the recent graduating class, two-thirds of the students are married with 37% of these students having one or more children. Over 66% of the students in the program come from states other than Utah and over 70% of the alumni reside outside of Utah. Additionally, over 60% of BYU chemical engineering students speak a second language fluently as a result of spending 1 ½ to 2 years in missionary service for the LDS Church, usually involving foreign residency. Examples of languages include Chinese, Croatian, Spanish, Korean, Russian, Samoan, German, Portuguese, Romanian, Swedish, and Japanese. This wide expanse of cultural experiences provides a unique global learning environment. BYU chemical engineering is thus national and international in scope and experience.



BYU Chemical Engineering faculty. L to R front row: Larry L. Baxter, Bradley C. Bundy, William G. Pitt, Dean R. Wheeler, John D. Hedengren, Thomas H. Fletcher. L to R back row: David O. Lignell, Thomas A. Knotts, Alonzo D. Cook, John N. Harb, Randy S. Lewis, Matthew J. Memmott, Morris D. Argyle, Andrew R. Fry. Not Pictured: Stella D. Nickerson, Douglas R. Tree, W. Vincent Wilding. Credit: Photo provided by BYU Chemical Engineering.

The BYU AIChE Student Chapter is very active and organizes a number of student activities including workshops, tournaments, tours, socials, and service opportunities. The chapter has also been instrumental in initiating one of the largest STEM career fairs in the west. The chapter started the career fair within the department in 1989 and now the career fair is run by the university after being led by the college for many years. More than 200 companies participate in the fall STEM career fair. The chapter has also co-hosted the AIChE Annual Student Conferences in association with the Annual AIChE meetings that have been held in Salt Lake City during the last decade. For their efforts, the BYU chapter has been recognized numerous times as one of the outstanding student chapters in the nation. In addition, other student clubs in which students participate include the Biomedical Engineering Club, the Society for Women Engineers, the Society for Petroleum Engineering, the Society for Biological Engineering, the Energy Club, the American Nuclear Society, and the Global Engineering Outreach Club.

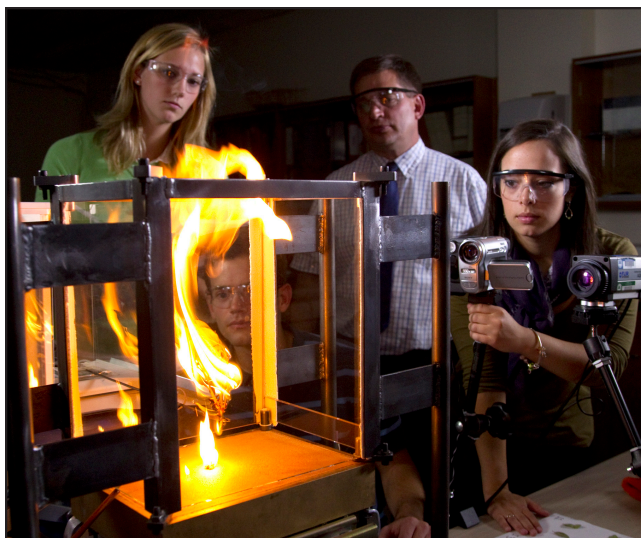
BYU has always focused on strong, exemplary undergraduate education with a robust supporting graduate research program. This effort is exemplified with nearly 75% of undergraduate chemical engineering students participating in student-mentored experiences—usually in research laboratories. Similarly, about two-thirds of the students participate in an internship or co-op experience before graduation. Nearly

30% of undergraduate chemical engineering students have also co-authored a published paper by the time they have graduated. A strong component of the educational experience for students involves experiential learning as well as the integration of graduate research with undergraduate mentoring.

Faculty hires since 2000 include Dean R. Wheeler (2002), Randy S. Lewis (2005), Thomas A. Knotts (2006), David O. Lignell (2009), Morris D. Argyle (2009), Bradley C. Bundy (2009), John D. Hedengren (2011), Alonzo D. Cook (2012), Matthew J. Memmott (2014), Andrew R. Fry (2016), Stella D. Nickerson (2016), and Douglas R. Tree (in 2017). The current hiring process will increase the full-time faculty size to 17, representing a growth of five faculty positions from 2009 to 2017. Strong research efforts continue in combustion, catalysis, sustainable energy, biomedical engineering, biochemical engineering, thermophysical properties, electrochemical systems, process control, polymer science, and nuclear engineering. Typically, 75% of the graduate students pursue Ph.D. degrees, with the remainder being M.S. students.

THE FACULTY

The current faculty members, including recent hires, are listed below along with a brief summary of their research areas. Additional research details are provided at <<https://chemicalengineering.byu.edu/index.php/departments/research>>.



*Fire research on live shrubs. Dr. Fletcher is shown with both graduate and undergraduate students.
Credit: BYU Photo.*

Morris D. Argyle—heterogeneous catalysis. Research interests lie in determining the structure/function relationships of heterogeneous catalysts applied to spectroscopic techniques, plasma reaction engineering, coal gasification, and new methods for carbon dioxide capture and storage. Current research projects include developing more stable and active catalysts for Fischer-Tropsch synthesis and the water gas shift reaction.

Larry L. Baxter—sustainable energy. Research interests include ways to provide energy needs of the current generation without compromising the resources of future generations. Current experimental and theoretical sustainable energy research includes carbon capture and storage, energy storage, biomass, black liquor, and coal combustion and gasification.

Bradley C. Bundy—biochemical engineering. Research focuses on a cell-free synthetic biology approach to engineering better therapeutics and a safe, renewable, sustainable chemical future. Applications of active research include cancer therapeutic optimization with polymers, biocatalyst immobilization optimization, vaccine development, genetic recoding, and biosensing endocrine disruptors.

Alonzo D. Cook—biomedical engineering. Methods are being explored to grow new tissues and organs from cells and proteins. Some of his current projects include heart, kidney, blood vessel, pancreas, nerve, and eye regeneration.

Specific research includes decellularization of pig organs, growing pluripotent cells, and 3-D printing of cells into the shape of organs.

Thomas H. Fletcher—combustion. Current research includes fundamental rates and mechanisms of pyrolysis, combustion, and gasification of low-grade fuels such as coal, biomass, oil shale, and petroleum coke, including NO_x formation and use of synfuels in gas turbines. Research also includes wildland fire ignition and soot formation from aromatic compounds.

Andrew R. Fry—combustion. Advanced combustion technologies are being developed that facilitate the continued use of fossil fuel resources in a carbon-constrained world. Of particular interest is combustion with oxygen at high temperatures and pressures to produce a pure CO₂ stream for sequestration. Pilot-scale experimental techniques are used to identify and overcome technological hurdles for deployment of new technology for power production. Co-firing of coal with biomass is also investigated with a particular focus on ash deposition.

John N. Harb—electrochemical engineering. Research covers a wide range of topics that are governed by electrochemical phenomena including energy storage devices (*e.g.*, batteries), energy conversion devices (*e.g.*, fuel cells), micro- and nano-fabricated electrochemical devices, and the fundamental processes that govern electrodeposition and dissolution. *Introduction to Chemical Engineering: Tools for Today and Tomorrow*, a popular textbook tailored for chemical engineering freshmen, is co-authored by John Harb and Kenneth Solen (retired).



Dr. Bundy and Dr. Pitt working with undergraduate and graduate students to engineer on-demand production of protein therapeutics. Credit: BYU Photo

John D. Heden-gren—process control and optimization. His research group, Process Research and Intelligent Systems Modeling (PRISM), is developing a world-class collaborative research group for the application of innovative advanced process control and optimization techniques. Research activities are focused on developing efficient modeling and optimization methods for large-scale dynamic systems.

Thomas A. Knotts—molecular simulation and thermophysical properties. His research group uses advanced molecular simulation techniques to investigate the biophysics of large biological molecules—particularly on surfaces.

The work aims to develop biomaterials, biocatalysts, and biotherapeutics to disruptively transform several industries including pharmaceuticals, detergents, textiles, catalysts, fuel, diagnostics, defense, sensing, and foods. He also works with W. Vincent Wilding on the DIPPR project, which is the gold standard for thermophysical and environmental property data and evaluation.

Randy S. Lewis—biochemical engineering and sustainable development. Research areas include safe, sustainable engineered solutions for developing countries with a focus on stoves, water purification, energy, and sanitation. Research also involves modeling biological interactions with nitric oxide and developing products and energy from biomass via fermentation and fuel cell applications. He is an instructor for the BYU Global Engineering Outreach (GEO) course which develops and implements humanitarian-based engineering projects.

David O. Lignell—combustion. Research involves computational modeling and simulation of turbulent reacting flows with an emphasis on combustion. Simulation and modeling research involves a one-dimensional turbulence model, direct numerical simulation, and large-eddy simulation.

Matthew J. Memmott—nuclear engineering. Research focuses on advanced reactor design, such as molten salt reactors.



Chemical engineering undergraduate student working with Peruvians to implement a water filter on the Uros Islands, Peru. This project was part of the Global Engineering Outreach course. Credit: Photo provided by GEO.

Additional research involves enhancing the passive safety of both current and advanced nuclear reactor technology while improving the economics, fuel utilization, and grid adaptability of current nuclear plants.

Stella D. Nickerson—ionic liquids. Research utilizes both molecular dynamics modeling and experimental work to understand ionic liquids and develop applications based on unique materials. Current emphases include ionic liquids as electrolytes and extraction media for separations.

William G. Pitt—biomedical polymers and drug delivery. Current research involves ultrasonic enhanced drug delivery which permits delivery of chemotherapeutic drugs to the sites of cancerous tumors without affecting the rest of the body. Drug delivery from contact lenses and rapid separation of bacteria from blood are also strong research areas.

Douglas R. Tree—soft materials and complex fluids. Research interests center on theory and numerical modeling of equilibrium and transport behavior of polymers across a variety of length and time scales. Recent projects have focused on the polymer physics of confined DNA and the dynamics of phase transitions in polymer materials.

Dean R. Wheeler—electrochemical engineering. Research includes modeling and experimental work to optimize lithium-ion batteries. Specific efforts involve understanding ion and



*The new engineering building currently under construction. The building will open for classes in Fall 2018.
Credit: Rendering Courtesy of VCBO Architects.*

electron transport in porous electrodes and improvement of manufacturing processes for low-impedance electrodes.

W. Vincent Wilding—thermophysical properties. Research involves thermophysical property measurement and correlation, environmental engineering, and process design. He is the lead investigator for BYU's Design Institute for Physical Properties (DIPPR), an AIChE initiative that has become the premier source of critically evaluated pure-component thermophysical and environmental property data.

A BRIGHT FUTURE: CONTINUING THE LEGACY OF A QUALITY EDUCATION

From humble beginnings to the current addition of a new 200,000-square-foot engineering building and annex for the Ira A. Fulton College of Engineering and Technology now under construction, the future looks bright. There is a broad consensus among the faculty about the mission and aspirations for the department. Most of these aspirations follow directly from the unique institutional mission and life experiences of our students. The faculty and institution place a high premium on undergraduate teaching quality. Teaching has a broad interpretation in this context and includes research programs that enhance teaching both by inspiring faculty and by providing mentorship opportunities for undergraduates and graduates, internships and coops with industry, experiential learning, and effective classroom instruction. The new facilities, larger and growing enrollments, and larger number of faculty will all make major contributions to this goal. In

addition to excellence in education, the department strives to build on the substantial international experience of the students to hone global leadership skills. The students in the department are exceptionally skilled academically, and their experience at BYU should enhance their ability to innovate and solve problems in practical and technically rigorous ways. Finally, but perhaps most importantly, the department places a high premium on character and citizenship and embraces the challenge of developing intellectual skills in parallel with gratitude, respect and appreciation for others, professional ethics, and discipleship.

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