The Northwest corner of the University of Alberta North Campus, with the engineering buildings in the foreground and the North Saskatchewan River in the background. (circa 2007, Courtesy of Creative Services, Office of External Relations, University of Alberta)

Chemical Engineering at The University of Alberta

Lucy Nolan, Fraser Forbes, and Ken Cadien

The year 1926 was a big one for Alberta; during this year, the Government of Canada gave the province control of its own natural resources.[1] It was also the first year in which the University of Alberta, in its 18th year of operation at the time, offered courses in chemical engineering. More than 85 years later, both the province of Alberta and chemical engineering at the University of Alberta have expanded on the back of natural resources but also diversified their interests. Both have become leaders in their fields. Chemical engineering at the university is now incorporated within the Department of Chemical and Materials Engineering, offering a uniquely cross-disciplinary blend of chemical and materials studies and process control. It has become the largest department of its kind in Canada, and one of the largest in North America and the world.

THE ADVANTAGE OF SCALE

As of October 2013 the Department of Chemical and Materials Engineering at the University of Alberta hosted 54 faculty and academic staff, including the dean of Engineering, 396 graduate students, and 640 undergraduate students.

These are supported by 44 full- and part-time technical staff members and 26 full- and part-time administrative staff members. Three quarters of these are engaged in chemical engineering or process control, with the remainder involved in materials engineering activities. Altogether, the department is the second largest granter of bachelor's degrees in chemical engineering in Canada, and the third largest granter of Masters and Doctoral degrees.

As a result, we are able to command some of the most extensive and well-equipped laboratory space in chemical engineering, including the National Institute of Nanotechnology (NINT) and the Alberta Centre for Surface Engineering and Science (ACSES). Facilities include distillation columns, fluidized beds and so on, characterization tools such as SEM and TEM, and delicate interfacial probes.

These world-class facilities are backed by world-class research support resources. This includes in-house specialized computer support as well as machine and instrument shops. An analytical chemist, a physicist, and an electron microscopist also maintain and operate analytical and characterization facilities such as SEM and XRD. Through the department's partnership with NINT, researchers in the department also have access to the quietest laboratory space in Canada.

The library at the University of Alberta is ranked 2nd in Canada and 11th in North America by the Association of Research Libraries.[2] The Science and Technology Library holds approximately 240,000 print volumes relating directly to engineering, and has electronic access to more than 61,000 standards from 15 different standards developing organizations.

These facilities allow researchers in the department to secure substantial funding from the federal and provincial governments and from industry. The total amount of research funding attracted to the department in 2011/12 was CAD$22 million, of which CAD$4 million was from corporate bodies. This is the highest level of industrial contribution of any department at the University of Alberta. The level of federal funding for research within the department is also higher than at any other university in Canada. These excellent resources allow exceptional faculty and staff to be recruited and retained, and facilitate the development of great research and training programs.

EXCELLENCE IN RESEARCH

Research within the Department of Chemical and Materials Engineering is focused in four main areas:

- *Energy and environment,*
- *Nanotechnology,*
- *Biomedical engineering, and*
- *Information and communications technologies.*

Significant achievements in these areas include the foundation of the Imperial Oil Centre for Oil Sands Innovation (COSI) and the Canadian Centre for Clean Coal/Carbon and Mineral Processing Technologies (C5MPT), and participation in the faculty-wide Helmholtz-Alberta Initiative (HAI). Research in the department has been advanced by the recruitment of Dr. Thomas Thundat, holder of the Canada Excellence Research Chair in Oil Sands Molecular Engineering. Dr. Thundat is one of only three Canada Excellence Research Chairs at the University of Alberta and 18 across Canada. There are currently only three Canada Excellence Research Chairs held by faculty members in Canadian engineering departments. Dr. Thundat is the only CERC in any Canadian chemical or materials engineering department. Dr. Carlo Montemagno has also recently joined the faculty of the department and is looking forward to expanding his ground-breaking work in bio-nanotechnology.

The publication rate of the department is comparable with similar departments worldwide, such as MIT, the University of Minnesota, and Georgia Tech in North America, and Imperial College in the U.K., as illustrated in Figure 1 (next page).

RESEARCH CENTERS

In support of the research areas identified above, the CME Department has established the following research centers:

Imperial Oil Centre for Oil Sands Innovation (COSI)

COSI was established in 2005 as a partnership between Imperial Oil, the Faculty of Engineering, and the Department of Chemical and Materials Engineering, under the leadership of Dr. Murray Gray. The success of the venture led to additional support and partnership from the Alberta Ingenuity

At a Glance: Chemical Engineering at the University of Alberta	
Website	http://www.cme.engineering.ualberta.ca/
History:	1908 University of Alberta founded
	1926 First Chemical Engineering courses offered
	1946 Department of Chemical Engineering founded
	1985 Process Control incorporated into Department of Chemical Engineering
	1996 Department of Chemical and Materials Engineering founded
Vital Statistics (As of October 2013):	396 Graduate Students (35% Female, 80% International, 45% Doctoral)
	640 Undergraduates (33% Female)
	33 Full Professors
	8 Associate Professors
	9 Assistant Professors
	3 Industrial Professors (2 in ESRM and 1 in Process Design)
	Mean faculty age: ~46 years

Fund (2007) and Alberta Energy Research Institute (2008). Following the reorganization of the provincial funding body, COSI is now partnered by Alberta Innovates Energy and Environmental Solutions. The national funding body NSERC has also provided support to the center through industrial research chairs and other grants programs. COSI currently has an annual research budget of approximately $3 million.

COSI has a strong research record, leading to the publication of 32 peer-reviewed papers since 2008. The unit is currently expanding its work by forming research partnerships with the University of Victoria, the University of British Columbia, Queens University, and the University of Ottawa.

Canadian Centre for Clean Coal/Carbon and Mineral Processing Technologies (C5MPT)

C5MPT was officially founded on June 24, 2012, as a partnership between the Department of Chemical and Materials Engineering, the Government of Alberta, and a number of industrial stakeholders. These stakeholders include Teck, Hatch, and Nexen, Inc. C5MPT aims to carry out research and education in the areas of clean coal, mineral processing, and carbon capture, under the direction of Dr. Qingxia (Chad) Liu, a faculty member in the department and scientific director of the center. The annual research budget for C5MPT is approximately $1.4 million.

C5MPT currently supports 10 fundamental research projects, of which nine are led by faculty members from this department.

Canadian Centre for Welding and Joining

The Canadian Centre for Welding and Joining was officially opened on May 5, 2010, and is led by Dr. Patricio Mendez in the newly established Weldco Industrial Research Chair. This center specializes in research on hard-to-weld materials, including embrittled and aged metals; technologies to improve quality and throughput; and non-destructive mechanical and corrosion testing.

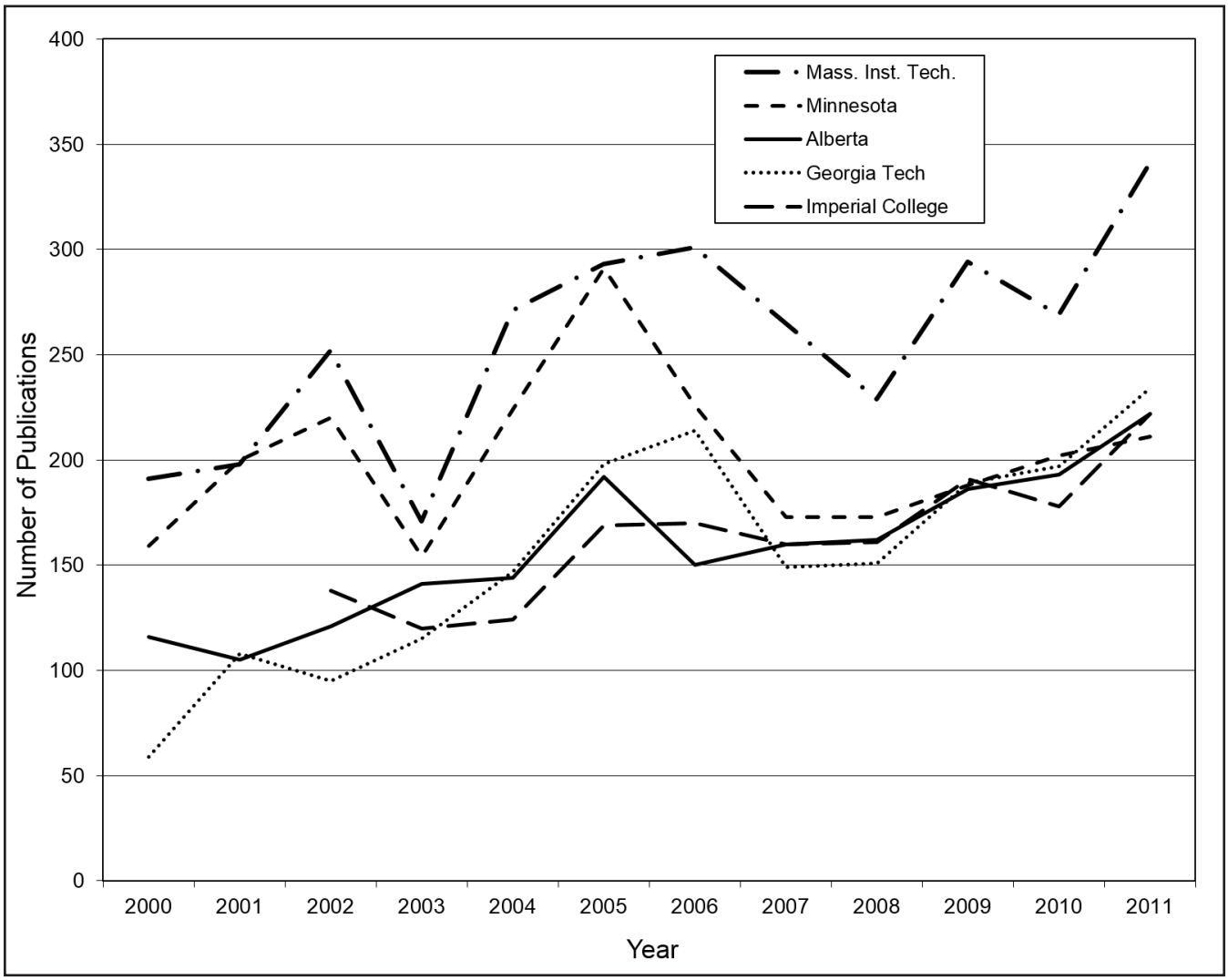


Figure 1. *Publications in chemical Eegineering, by university, 2000-2011.*[3]

Additionally, many of the NSERC Industrial Research Chair programs that are led by CME faculty (such as Drs. Xu, Huang, Shaw, and Kuznicki) may be considered as small to medium scale collaborative research groups in which other faculty are deeply involved.

INDUSTRIAL PARTNERSHIPS—IDEAS IN PRACTICE

The practical focus of much of our research naturally leads to industrial collaboration, and we recognize that seeing good ideas through to commercial implementation can be immensely satisfying for today's researchers. The successful marriage of academic discovery and industrial commercialization is an important part of our history. Dr. D.B. Robinson was a faculty member here from 1948 to 1971, holding the position of department chair from 1958 onwards. After leaving the department to form his own business—applying his fundamental research to the oil and gas industry—he continued to research and supervise students. This lead to the 1976 publication of the Peng-Robinson Equation of State in conjunction with his Ph.D. student Ding-Yu Peng. The paper describing their discoveries has since been cited nearly 3,500 times, making it one of the most widely cited in chemical engineering.

Dr. Jacob Masliyah continued this tradition of innovation while an active faculty member, from 1978 to 2010. He held the NSERC Industrial Research Chair in Oil Sands Engineering for 15 of these years, and the programs and innovations developed in his labs now underpin industrial practice. He was awarded the Order of Canada in 2006 in recognition of his contribution to the industry, and has been made a Fellow of both the Royal Society of Canada and The Canadian Academy of Engineering.

Eight NSERC Industrial Research Chairs (IRCs) are held within the department today. These are in a range of fields, from oil sands upgrading (Dr. Murray Gray, Dr. John Shaw, Dr. Zhenghe Xu, and Dr. Anthony Yeung) to pipeline processes (Dr. Sean Sanders), process control (Dr. Biao Huang and Dr. Sirish Shah) and molecular sieves (Dr. Steve Kuznicki). The current department chair, Dr. Fraser Forbes, and associate chair-graduate program, Dr. Ken Cadien, have both entered academia from industrial research positions and bring their strong emphasis on practical solutions for real-world problems to the department.

All researchers additionally have access to the research commercialization services of TEC Edmonton—a unique, not-for-profit joint venture between the University of Alberta and the Edmonton Economic Development Corporation (EEDC).

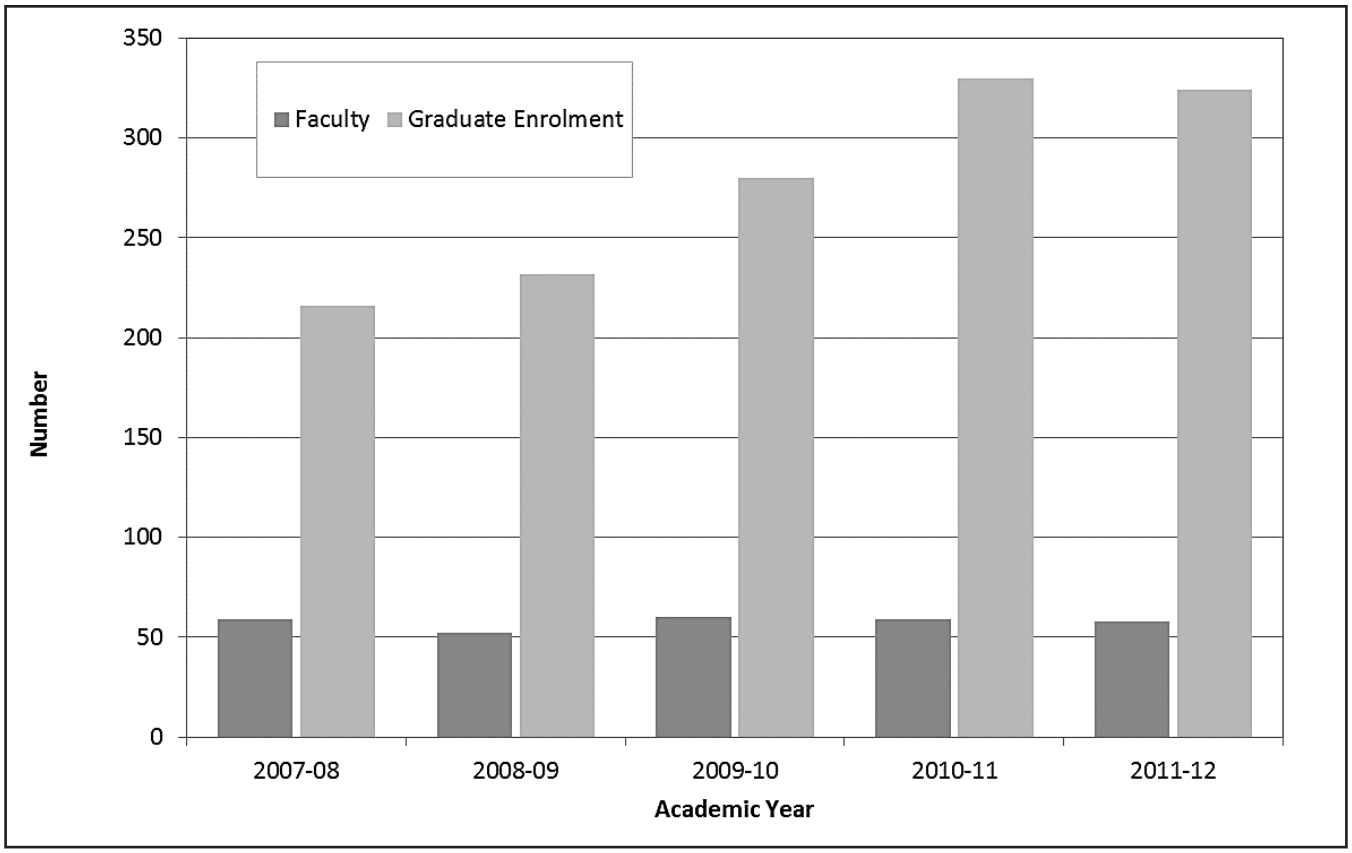
EXCELLENCE IN TEACHING

Our department has been committed to teaching excellence since its inception and has a long-standing culture of striving for excellence in our educational activities. Industrial need for engineers in Alberta continues to expand, and with that demand the size of our graduating class has more than doubled since 1996. At the same time, our graduate student population has more than tripled. In the face of this rapid growth and increasing class sizes, the need for excellent teaching is always at the forefront. The continuing active involvement of our alumni in the mentoring of design projects and co-op students is a cornerstone of our continuing success. A number of these alumni have now returned to the university as industrial teaching chairs on five-year contracts.

Gord Winkel, formerly vice president with Syncrude Canada, leads our Engineering Safety and Risk Management (ESRM) program. This program provides two safety and risk management courses to most of our approximately 850 fourth-year students and lectures to all of the design courses in the faculty, as well as the incoming and graduating students.

Bill Pick, former Global Technology leader for Dow's light hydrocarbons business, is our William Magee Chair in Process Design. He is at the hub of a team of eight design instructors who offer our two final-year design courses to a graduating class of 120 students. These courses provide a combined 85 student projects every year to teams of four or six students. Each project is a current industrial problem with an industrial mentor. The design courses have advanced dramatically over the last 10 years, now providing structured milestones with intermediate reports, regular review meetings, short modular lectures on special topics, and explicit coaching in teamwork. Our design team includes some of our most successful industrial collaborators on the research side, most notably John Shaw (NSERC IRC), Murray Gray (COSI PI and former NSERC IRC), and Arno deKlerk.

Our faculty members have been recognized with some of the highest teaching awards at the University of Alberta (6), the province of Alberta (2), and Canada (3). Dr. John Nychka, hired for his outstanding achievements in educational design, has been awarded Provost's Award for Early Achievement in Undergraduate Teaching, the Association of Professional Engineers and Geoscientists of Alberta (APEGA) Excellence in Education award and Canadian Council of Professional Engineering (CCPE) Medal for Distinction in Engineering Education, and a Rutherford Award for Excellence in Undergraduate Education—all in his first six years at the U of A. John leads our second-year materials engineering course and has developed a set of in-class demonstrations for the course. These demonstrations started their life in his iconic "What's in the Box" box. The box has now self-replicated to student kits, which fit neatly into a backpack. The students now sit in class and explore the mysteries of materials as part of their lectures—150 students at a time. The energy in the classroom is electric. Dr. Suzanne Kresta was honored by Engineers Canada in 1998 for the initial development of the New Faculty Forums (Young Engineer Achievement Award),



Graduate student and faculty numbers in the Department of Chemical and Materials Engineering at the University of Alberta, from the 2007/08 academic year to 2011/12.

and Rutherford Undergraduate Teaching Award and APEGA Summit Award for Excellence in Education. Dr. Uttandaraman Sundararaj, while a faculty member in our department, was honored with the Engineers Canada Medal for Distinction in Engineering Education in 2008, followed by a 3M National Teaching Fellowship in 2010.

Other faculty members have developed faculty-wide teaching initiatives, most notably the (New) Faculty Forums, which have now introduced the basic principles of educational theory to 160 of our 200 engineering faculty members. Last year, at the insistence of a number of alumni of the program, the forums were redesigned as ongoing professional development sessions for all faculty, and renamed the Faculty Forums. This work has provided the momentum for several teaching workshops that have brought in experts from around the world.

Our department prides itself on encouraging the growth of students in all aspects of their lives. Chemical engineering students comprise some of the top athletes at the University of Alberta, including Brendan Bottcher, the skip of the 2012 Alberta, Canadian, and World Junior curling championship rink, and Amanda Schneck, the U of A's 2011 Female Academic All-Canadian of the year. Students with an interest in working during their studies may participate in the Co-op program, which places 280 students in 20 months of employment interspersed with their studies. Students with an interest in research are encouraged to participate in the Dean's Research Project, a faculty-wide program that places high-achieving students with an adviser to conduct their own research.

Students increasingly participate in international work or study terms, including recent placements in Germany, Norway, and France, and many of our graduates work globally after they graduate. Although not required in Canada, many students choose to sit the Fundamentals of Engineering exams to allow them to practice in the United States. The excellent teaching practices adopted by the department are demonstrated by the 96% pass rate for our chemical engineering students since 2003, compared to an average rate for the same period of around 83%.

REFERENCES

1. <http://www.collectionscanada.gc.ca/05/0529/052930/05293055_e.html>
2. 2011 ranking; <http://www.arlstatistics.org/analytics>
3. This data is compiled annually by Jude Sommerfeld of the Georgia Institute of Technology from the Science Citation Index (Expanded)® in the ISI Web of Knowledge®. This is estimated to capture 85% - 90% of publications across the 220 institutions analyzed worldwide. ❐