North American Engineering Education & Academic Exchange:
-- Canada, Mexico, the United States --

Thomas R Phillips, ABET/FIPSE Project Consultant
Managing Director, Collegeways Associates (USA)

From 1993 to 1996 the author served as 'External Evaluator' for the Regional Academic Mobility Program (RAMP), a multilateral exchange program run by the Institute of International Education (IIE). RAMP has brought together 26 institutions in Canada, Mexico, and the United States, moving over 200 students in its first three years. However, only about 12% of the exchanges have involved U.S. students. One of the impediments to recruitment has been a lack of timely, consistent, and useful information on programs.

The author obtained a FIPSE/USDE grant to develop a guide, consisting of institutional and program profiles, curriculum tables, and selected course descriptions. French and Spanish materials were translated and converted to a standard format. The resulting Guide contains examples of over 100 Canadian and Mexican engineering programs across seven disciplines. The observations in this paper are based primarily upon information from the RAMP institutions.

Engineering Education in North America

I wanted to determine how a U.S. engineering student could benefit from studies in Canada or Mexico. Was there a professional rationale to support a marketing concept and strategy for the RAMP program? I soon found similarities among the course descriptions and curriculum charts. The topics listed in the standard engineering courses were much like ours – not surprising with the use of standard textbooks and software.

Not so apparent is an emphasis on applied engineering skills that increases as you go from Canada to Mexico. In fact, Mexican universities feel that one of their strengths is a comparatively high percentage of faculty members who teach and work in industry. This is viewed as a positive feature in the preparation of graduates for jobs in Mexico's "productive sector." While this approach favors industry, it slows faculty development in Mexican universities. Even some of the larger engineering schools have a comparatively small core of full-time faculty with advanced degrees, and relatively small graduate engineering programs.

Mexican mechanical and electrical engineering courses often include topics on design for manufacturing, manufacturing process design and control, fabrication, and applications of computers and electronics to manufacturing. Mexican civil engineering programs emphasize competency in construction, while chemical engineering programs serve the processing industries in chemicals, food, and materials. Mexican programs usually have an "industrial engineering" component, focusing more on the practical problems of industrial plants, facilities, and production management, and less on quantitative methods. Courses in labor law and personnel management are standard requirements. Mexican engineering students are taught design, but- also learn to "install, operate, and maintain" electronic, mechanical, and industrial equipment.

Given Mexico's growing manufacturing base, emphasis on infrastructure development, and the number of U.S. employers with operations in Mexico, a U.S. exchange student could create a valuable, marketable learning experience. In both Canada and Mexico, I saw opportunities for student projects and practical experience that would enhance a resume.

We need to make our students understand that such experiences are of interest to employers who operate throughout the Americas. We need supporting statements from employers, perhaps those who are represented on the industrial advisory committees of schools and departments.

The Canadian RAMP schools offer interesting opportunities for manufacturing-related studies in electrical, computer, and mechanical engineering. They have comparatively large selections of specialized "Option" courses, many with industrial advisors and access to industrial projects. Both Canada and Mexico have strong programs in geodesy, geology, geomatics, hydrology and water resources, mining and minerals engineering, and power. These specialties serve national priorities that differ from those of the United States.

Although Canadian and U.S. engineering education has many similarities, Canada places more emphasis on practical engineering skills. I found Canadian programs in which 16 lecture hours are accompanied by 9-14 "lab" hours. Canadian and Mexican programs have a higher percentage of technical credits, and even in the "non-technical" or "complementary" area, the courses tend to build professionalism more than breadth.

Specialized subjects appear a bit earlier in Canadian and Mexican programs. This allows Canadian third and fourth-year students to take advantage of specialized option courses, industrial internships, and projects. Mexican students must get through a lot of material in the middle years, to be eligible for a major project or thesis and 480 hours of social service, typical requirements for a professional title. This leaves Mexican students with much less time for electives. With limits on time and industrial support, there seem to be fewer opportunities for internships.

The U.S. programs in the sample made a more concerted use of computer applications, did more to integrate design, but did not have the same emphasis on manufacturing as Mexican programs. Given the priorities of Mexican industry, our emphasis on design might be misplaced in Mexican programs. One industrial priority is the manufacture of products designed in the U.S. or Asia. However, some Mexican engineering educators feel that Mexican engineers could do the same design work, better adapted for manufacturing in Mexico, at a cost that would make a NAFTA trading bloc more competitive against the Asian manufacturers.

The best way for an exchange student to exploit these opportunities is to develop an overall exchange concept and goal – e.g., to gain an understanding of manufacturing engineering in Canada or Mexico. This could be done through a combination of courses, projects, and industrial contacts. This is better than making the direct equivalency of courses the first priority. The objective should be to transcend the similarities and to learn what is different and distinctive. The next step is to present exchange a learning project, We train our students to plan and carry out engineering projects, so why not approach exchange in the same way? Now we will turn to some basic comparisons of the three systems.

Credit Systems: Mexican courses carry 6 to 10 units, usually two units or credits for each hour of lecture, and one unit for each hour in laboratory or working groups. Some schools assign units for the time spent on practical work, class projects, or outside assignments. In general, a 6-unit course is three lecture hours per week without a laboratory, while 8-unit courses have three hours of lecture plus lab or practical work. Mexican semesters can be as long as 18 weeks, with 2 weeks for examinations. Thus, a 6-unit course represents about **48** hours of classroom time. Canadian students who went to Mexico through RAMP thought the workload was lighter, simply because they had more time to do comparable work.

Canadian engineering courses generally have 13 to 15 lecture hours per credit, so that a three-credit course contains about 45 classroom hours – much like the U.S. One credit can represent up to 3 hours of laboratory time, depending on the amount of supervision, or 3-6 hours per week in a working group. A Canadian "trimester" has 13 weeks in class, followed by a 2-week reading and exam period, making it more like a U.S semester with a heavy work load.

Length of Study: The typical Canadian program covers four years or eight trimesters, with 4.5 years as the average length of study. Programs in Quebec run from four to four and a half years on paper, but Quebec students usually enter with the equivalent of a year of university mathematics and science. Some Canadian departments have adopted a five-year trimester plan to accommodate cooperative work/study programs.

Mexican programs usually run for 9 to 10 semesters, on paper. Even on the more competitive campuses, up to 2/3 of the first-year students may take preparatory or supplemental coursework, lengthening their time in school. The Licenciatura (bachelor's degree) is based upon coursework, but students often need more time to complete the graduation requirements for a professional title.

Prerequisits: Most Canadian programs have a one-year "common trunk", followed by a cluster of "specialized" courses that form the major. The option courses either have stated prerequisites, or a total credit threshold. Mexican programs typically have a 4 - 5 semester core program of mathematics, basic science, and engineering fundamentals in a traditional, tightly-ordered sequence. Strict rules govern examinations, withdrawals, failures, and the number of 'attempts' permitted in any given course.

Textbooks: Mexican universities often use standard engineering textbooks, in Spanish or English, many published by McGraw-Hill, Harper & Row, Prentice-Hall, and Wiley. Technical reference material often comes direct from U.S. manufacturers. Although faculty members in the largest schools sometimes use their own text and course notes, the use of standard textbooks and reference materials has helped to standardize prerequisites, lesson plans, and examinations. Standard texts are also used in Canada, although the French-speaking institutions sometimes use an English-language text along with French-language texts and lecture notes. I found a relatively small number of courses with just a French-language text.

Laboratory. Practical Work, and Workload: When looking at Canadian and Mexican courses, the time spent in lecture classes is not the key to understanding the workload and learning experience. An evaluator needs the course descriptions, curriculum charts, and bulletin. The trick is finding where the laboratory or practical work is located and to what extent that work is reflected in the nominal course credit. There are general formulations for credit in Canada and Mexico, but differences can be found in the policies of individual institutions.

Canadian programs seem to be conservative in giving credit. For example: 1) A course description for 'Dynamics of Mechanical Systems' indicates three credits, but the course actually consists of four hours lecture and one hour of lab. 2) A standard course in Electromagnetic Fields shows three credits for three hours lecture and one hour lab per week. The same course at another school is four credits, including unspecified time in recitation groups. 3) A three-credit course in Operating Systems consists of three hours lecture plus three hours lab per week. 4) The sixth semester of a mechanical engineering program has 16 lecture hours, but the students also have 9.5 hours of laboratory work. Some departments have up to 14 hours of lab or practical work, along with a full complement of lecture hours.

A number of Canadian schools use a compressed course description, showing the time budgeted for TA's, the size of lab sections, but rarely a breakdown of laboratory topics. When a Canadian lecture course has a lab, it tends to be specific, to that course, rather than a free-standing lab course. Many programs have 3-6 hour intensive laboratory or project courses in the last 2-3 terms.

Mexican course descriptions can be difficult to obtain, and even then, may omit details on prerequisites, computer skills, lab and practical work, and design content. Apparently, government regulatory practices do not require faculties to prepare such documentation. It is difficult to get details on the practical work in Mexican courses – it may be that Mexican faculties take this for granted and don't feel that it needs explanation. Design topics seem to appear in the courses where you would expect to see them, but Mexican faculties do not have to document design content or competencies as we do in the U.S. and Canada. The regulatory system focuses more on the thesis, professional exams, and the social service requirement.

A Mexican course with more than six units indicates lab or practical work beyond the usual classroom exercises. However, course descriptions often list the lecture topics without breaking out the related lab or practical work. Some 8-unit courses consist of six lecture units, and two units for computer assignments and student projects.

Computer Use: Computers and software operate as agents for international cooperation. RISC-6000 systems, SUN Sparc, and HP workstations are in wide use, along with the popular brands of PC's, MAC's, printers, and peripherals. English-language software has become a vehicle for cross-cultural communication, providing a communication standard for everything from quantitative analysis, to engineering design, project management, and economics. Some of the software packages in common use include: Word and WordPerfect, Lotus and Excel, Aspen, AutoCAD, Hysim, Spice/Pspice, and a host of similar programs for numerical analysis, process analysis and design, project planning, structural analysis and design, simulation, etc. A group of Mexican department heads told me that they use English-language software, because this helps students to develop language skills and prepares them for work with U.S. companies.

Much like the U.S., Canadian institutions usually have a networked software library in addition to departmental resources. Mexican university computer facilities tend to be centralized, either at an institutional or divisional (faculty) level, while individual departments (programs) have less equipment of their own. Whatever the differences, reports from returning exchange students indicate very few problems related to the use of computer hardware or software.

Canadian Engineering Education

Canadian students complete 12 years of schooling before entering the university. All of the universities in the sample have specific requirements. in terms of high school subjects and marks. Basically, students are expected to start Calculus, Chemistry, and Physics upon entering the university. Budget cuts have forced many Canadian engineering schools to adopt enrollment caps, which justify strict admission requirements. Quebec has eleven years of schooling, followed by two years in a "College d'enseignement General et Professionnel" (CEGEP). The CEGEP academic track combines a final, focused year of high school, plus the equivalent of the first university year in other provinces. Applicants to Quebec engineering schools need the "Diplôme Enseignement Collégiale" (DEC), specialized in science. Traditionally, U.S. credit evaluators have allowed credit for the second year of the CEGEP.

Canadian Program Reauirements: The Canadian Engineering Accreditation Board (CEAB) of the Canadian Council of Professional Engineers (CCPE) accredits 228 programs in 33 institutions, including the RAMP institutions. The content of an accredited Canadian program is organized in four areas: The ***Common Trunk*** or core program (about **30** credits); a ***Specialized Trunk*** of required courses for the major (65-75 credits); ***Complementary*** courses to broaden the professional preparation of the student; and ***Option*** courses to form a technical specialization (known as an Option, Orientation, or Concentration).

CEAB minimum requirements are expressed in units, each representing at least one 50-minute lecture hour. Each program must have a minimum of **1800** units.

Mathematics: a minimum of **195** units of mathematics including appropriate elements of linear algebra, differential & integral calculus, differential equations, probability, statistics and numerical analysis.

Basic Sciences: A minimum of 225 units of basic (natural) sciences, such as elements of physics and chemistry and, where appropriate, elements of life sciences and earth sciences. These subjects must include the use of analytical and/or experimental techniques.

Engineering Sciences & Engineering Design: A minimum of **900** units that combine engineering sciences and engineering design, with at least 225 units in each area. This leaves **450** units for any desired combination (integration) of engineering sciences and engineering design

The CEAB and ABET definitions of engineering design contain similar references to constraints in the design process – i.e., standards or legislation, and the economic, health, safety, environmental, and social factors.

Complementarv Studies: A minimum of 225 units of studies in humanities, social sciences, arts, management, engineering economics and communication that complement the technical content of the curriculum.

Given the limitations on space, we must move on to the Mexican system. It is not as well understood and needs a bit of explanation.

The Path for Mexican Engineering Students

Professional engineering education is concentrated in the public universities, and in certain private institutions. Public universities represent only 5% of Mexican postsecondary institutions, but serve 86% of the students in 34 state universities, the Universidad National Autonoma de Mexico (UNAM), three campuses of the Universidad Autonoma Metropolitana (UAM), and several specialized colleges and schools. About 20% of Mexican universities are privately supported.

The critical preparation for would-be engineers occurs in the **'*Prepuratoriu*** ', a three-year upper secondary program offering specializations in physical & mathematical sciences, and chemical & biological sciences. Upper-secondary graduates receive the "Certificado de Bachillerato." Although Mexican engineering applicants usually have the same upper-secondary subjects, the universities often complain about uneven preparation. Universities routinely give diagnostic examinations in mathematics and language skills, and many engineering schools list algebra and geometry as first-semester supplemental courses along with Calculus 1.

Given the faculty complaints about uneven preparation, it is ironic that Mexican upper secondary schools are normally operated or recognized by the universities that receive their graduates. University faculties often dictate the subjects and marks required for admission. Some faculty complain that secondary school recognition depends more on the relationship to the parent university than actual quality assessment. Mexican universities typically admit graduates from their secondary schools first, and only then graduates of outside "incorporated' schools. For example, 85% of the entering students at the UNAM come from its secondary school network.

Admissions: Selectivity is determined at the institutional level. Mexican students are usually commuters, because they apply to the university that operates or "incorporates" their upper secondary program. Residence halls are a rare commodity in the public sector, and few can afford the additional cost. The threshold for admission is normally a scholastic average of 70% and comparable entrance exam scores. In fact, the diagnostic exam is what really matters. On some campuses the entrance and diagnostic examinations are one and the same. A Mexican engineering school may say that its entering students come from the top 10% of students who qualify for university admission, but most of the students come from nearby affiliated high schools. Transfers account for less than 10% of the entering students in most engineering schools. Instead of using branch campuses as feeder schools, several of the larger public institutions are attempting to decentralize, by offering full engineering programs on branch campuses. Transfer is difficult, due to intense competition, cost factors, and a "revalidation" exam requirement.

Quality Assurance: The oldest university in Mexico is the Universidad National Autonoma de Mexico (National Autonomous University of Mexico). UNAM programs have served as models for a number of institutions, which may explain the structure of many Mexican programs and courses. Some Mexican educators disagree with the UNAM model, so you will find programs that vary in emphasis, length, occupational objectives, and the industries they serve. It is said that the private sector has been more innovative in recent years.

University policies discourage part-time study and restrict the number of times that a student can attempt a course. Students are expected to make up any missing courses, incompletes, or failures before attempting new courses. The demand for seats is intense, so students are under pressure to maintain progress. Mexican universities use both descriptive and numerical grading, but in either case, the lowest passing grade is also the lowest grade allowed for graduation. There is no equivalent of a "D" grade, or grade that would not satisfy graduation requirements.

The recognized Mexican engineering accrediting body is the **Consejo de Acreditacion de Las Ensenanze de La Ingenieria A.C. (CACEI).** CACEI has largely developed since 1992, as a cooperative effort of the Mexican engineering deans, university groups, professional bodies, and government. CACEI has established comprehensive and detailed criteria for Mexican engineering education, with faculty development, teaching load, and full-time percentages as three of the most significant items. By June, 1996, four programs had been accredited: Industrial Engineering, Instituto Politecnico National, Mexico, D.F.; Civil Engineering, Universidad Autonoma de Yucatan; Civil Engineering, Universidad Autonoma de San Luis Potosi; and Electronic & Communications Engineering, ITESM - Monterrey.

Comparison of standards for the minimum number of hours in an engineering program:

Mexico - CACEI Minimum Standard	U.S. - ABET Minimum Standard
Basic Sciences & Mathematics 800 hours/ 3 1%	Basic Sciences & Mathematics 25%
Engineering Sciences 900 hours/ 35% (no overall design criteria)	Engineering Topics, with design, 1.5 years/ 37.5%.
Industrial Engineering 400 hours/ 15%	No direct equivalent
Social Sciences & Humanities 300 hours/l 1%	Humanities & Social Sciences, ½ year/12.5%
Other Courses 200 hours/ 8%	Other Courses (not specified, but can go to 12%)

The "Industrial Engineering" category includes industrial applications for each discipline (e.g., electronic manufacturing & fabrication for an E.E. student). CACEI has defined the essential "thematic" and applied engineering topics for programs in each discipline. Design is addressed within individual courses, rather than as a criteria category.

The Secretariat de Educación Pública (SEP) maintains a Professional Directory of graduates from recognized programs who complete SEP-approved graduation requirements. The SEP does not do substantive program evaluations, nor does it specify the actual ***content*** of programs, thesis projects, or the professional exams given by faculty. Content is determined by the faculty at each recognized institution. Most of the documentation required by the SEP deals with the administrative procedures surrounding these program features. The SEP has started an examination program known as CENEVAL, which is both a professional exam and a measure of program effectiveness. At present, there is one examination for civil engineering.

Central advisory councils are involved in curriculum development. CONACYT (the National Technical Council of Education) is a consulting body run by the SEP. Planning is a joint activity of the SEP and ANUIES (the National Association of Universities and Institutions of Higher Education), an organization with extensive research and publications activities. ANUIES serves as a consulting and advisory resource, but like CONACYT, does not make rules or accredit programs.

Historically, the official "validity" of Mexican programs has depended on the legal status of the institution, rather than direct quality assessment. Mexican university engineering programs must have official validation in order for their graduates to be listed as professionals. Institutions chartered by governmental agencies automatically receive validation. A few private institutions have a free or independent charter, which carries validation. Most private institutions have to obtain "incorporation" through an institution with primary official validity. Thus, engineering programs at private universities tend to resemble the programs of the incorporating public universities. When institutions obtain the direct recognition of a government agency, their programs often resemble others recognized by that agency. Thus, the validation process exerts a standardizing influence, which may or may not promote quality improvement. Incorporation through another institution applies to specific programs, but **not** to the entire institution. One argument for accreditation is that validation requirements may be unevenly applied when the programs of private institutions are "incorporated" or recognized by different public institutions.

In the larger engineering schools, a number of departments may be administered within one Faculty: e.g., a Faculty of Mechanical & Electrical Engineering with nine or ten programs, some rather large. Many programs may come under one master plan for academic standards, curriculum, teaching methods, and budget support. This promotes standardization, but may discourage innovation or fund-raising efforts by individual departments. Several institutions in the sample are moving to a departmental structure to gain more flexibility and control at the program level.

Change is also determined by funding. Mexican faculty members state that that there is no strong tradition of industrial support for engineering education, in funds, equipment donations, or program development. This may explain why computing facilities are more centralized, and why individual departments have little to report on industrial grants or sponsored internships.

Program Characteristics: Mexican universities tend to organize around disciplines, rather than groupings such as "arts and sciences." For example, one university has a Faculty of Industrial and Mechanical Engineering that administers eleven programs, some equivalent to departments. Students receive more of their general education in upper secondary school, and directly enter university programs that are more applied and specialized in terms of occupational outcomes. Mexican students may take all of their courses under one Faculty, even the non-technical subjects.

Most programs follow a traditional sequence of mathematics, science, and engineering courses, presented in a standard lecture and examination format, Integration is pursued through laboratory, practical, and project work that is built into the standard courses. Design competency is not emphasized in Mexican program materials, and while design content appears in course descriptions, it tends to be understated. It may be that Mexican industrial requirements influence how schools describe their programs, courses, and the competencies of graduates. Design competency receives explicit attention in Canadian and U.S. program materials, because it is a key accreditation requirement and program outcome.

Mexican program and course descriptions also understate the use of computers as an element of professional preparation. Mexican engineering students most certainly use computers for engineering studies and projects. Canadian students who studied in Mexico were satisfied with this aspect of their courses. Mexican exchange students reported no problems with computer assignments while in Canada and the U.S.

Although the amount of elective credit has increased, Mexican programs devote less time to the humanities and social sciences. Some schools offer thematic "technology and society" courses. In addition to Communications skills, all students take English as a second language, while comparatively few U.S. engineering students go as far in "foreign" language.

Mexican students must complete up to 480 hours of social service. The SEP-approved graduation requirements for a professional title may also include a thesis or final project, or in some institutions, a professional examination formulated by the faculty. As previous stated, very few programs appear to have an internship or formal work experience, probably due to the time needed for social service and insufficient industrial support.

Some engineering schools describe the social service assignment as "professional practice and social service," while some emphasize public service. Some Mexican faculty members view this non-credit experience as more "social" than professional. Students receive a certificate that verifies completion of the social service requirement and the place of employment.

Evaluation: As previously noted, some students complete the course requirements for the Licenciatura without completing the requirements for a professional title. Students can obtain a "constancia," a list of courses taken and grades earned at an institution up to a given time.The constancia is a temporary document that different university offices may issue for different purposes. It may not reflect a completed program, and should not be accepted as proof of graduation.

There is no inherent reason why well-documented individual courses cannot be accepted for credit. However,. there can be problems at the problem level. Some Ingeniéro (Ing.) titles are in fields that do not fall within the scope of ABET or CEAB accreditation – e.g., we don't have "engineering" titles in fisheries, horticulture, food production, and aquaculture. Program objectives may also differ. For example, you may find a Mexican industrial engineering program that provides a strong interdisciplinary education, while coming in light on engineering content. It is important to consider both the courses and the program that they form.

Graduates should be able to furnish the "certificado de estudios", an official transcript of all courses and grades, as well as a formal diploma. When the issue is completion of an engineering degree, evaluators should: 1) determine the graduation requirements approved by the SEP for the program in question; 2) verify completion of the appropriate requirements (social service, thesis, research project, or departmental professional examination); and 3) determine whether the graduate was approved for listing in the SEP General Directory of Professions as an engineer; and 4) determine that the Ing. title is in an accepted engineering field. Graduates listed in the SEP General Directory should be able to produce a professional certificate or "cedula."

Conclusion: U.S. students should give serious consideration to a semester or year of study in Canada or Mexico. The goal should be an understanding of some area of engineering practice, such as manufacturing or construction. Future employers will most likely have North American interests or operations that call for engineers with this knowledge.

Although there are certain similarities, the differences are interesting – courses with strong applied engineering content, opportunities for team-based work, faculty with strong industrial backgrounds, and courses with industrial advisors.

Course and credit evaluation is less of a concern with Canada, because of similarities in our educational, accreditation, and industrial systems. It is difficult to obtain comparable information on Mexican programs and courses. Mexican institutions do not engage in marketing and recruitment as we know it, so there is less information for prospective students. Advising is different, because students have relatively few options. Above all, regulatory practices determine what information Mexican institutions keep on hand. Evaluations should be done on two levels – first, the content of individual courses, and second, overall program content and objectives. It makes a difference if you are evaluating individual courses for transfer, or evaluating a degree program for the purpose of professional recognition.

Proposals for exchange programs should include a marketing concept, strategy, and recruiting tactics. That assumes an understanding of the information required by faculty and students, and what will actually be available. It is wise to seek funding for structured, task-oriented faculty visits in the first few months of an exchange program. This may provide the knowledge that faculty advisors need to help students develop an overall concept and project approach for study abroad.

Readings

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Biographical Information: Thomas R. Phillips

From 1987 to 1994, Mr. Phillips served on the staff of ABET. He is the Managing Director of Collegeways Associates, a consulting firm serving professional societies, international education organizations, institutions, and students. He is completing a FIPSE-funded project known as the "North American Engineering Exchange Guide." He has served as a USDE/FIPSE reviewer and as an evaluator on projects of the Institute of International Education (IIE). He co-authored a comparative review of 21 European university engineering programs, published in the Netherlands in 1993. In 199 1, he authored the ABET/Exxon Engineering Student Achievement Profile, a study of 2,400 minority and non-minority engineering students from secondary school through graduation. Before joining ABET, Mr. Phillips was Dean of Admissions at the School of Engineering & Applied Science of Columbia University. His work in university admissions and student services spans 17 years.