01 Jan 1992

Educating Engineers To Manage Technology: An International Comparison

Daniel L. Babcock
Missouri University of Science and Technology

Brian E. Lloyd

Recommended Citation

D. L. Babcock and B. E. Lloyd, "Educating Engineers To Manage Technology: An International Comparison," *Proceedings 1992 IEEE International Engineering Management Conference: Managing in a Global Environment, IEMC 1992*, pp. 248 - 252, article no. 225264, Institute of Electrical and Electronics Engineers, Jan 1992.
The definitive version is available at https://doi.org/10.1109/IEMC.1992.225264

EDUCATING ENGINEERS TO MANAGE TECHNOLOGY: AN INTERNATIONAL COMPARISON

Daniel L. Babcock
University of Missouri-Rolla
Rolla, Missouri 65401, USA

Brian E. Lloyd
EPM Consulting Group
Brighton East
Victoria 3187, Australia

ABSTRACT

Two countries, the United States and Australia, are compared in terms of:
(1) the historical growth of their engineering professions;
(2) the structure of their engineering professional organizations;
(3) the prevalence of engineers in management positions; and
(4 the education of their engineers for management responsibilities.

GROWTH AND EDUCATION OF THE ENGINEERING PROFESSION

United States. While the U.S. Military Academy, established just after the American Revolution, was the first American military school, the event that had the greatest influence on engineering education was passage of the Morrill Land Grant Act in 1862. This act gave federal land (ultimately 13,000,000 acres, an area 46% larger than Taiwan) to each state to support "at least one college where the leading object shall be...scientific and classical studies...agriculture and mechanic arts." This made education in the "mechanic arts" (which became engineering) available and affordable throughout the country. By 1928 president-elect Herbert Hoover (himself a distinguished engineer and manager) could say:

> The leaders of our universities were the first of all the educators of the world to...provide fundamental training in the application of science to engineering under the broadening influence and cultivation of university life....[Another] dimension that grew in American engineering was the transformation from solely a technical profession to a profession of administrators - the business manager with technical training.[1]

Australia. Formal education for engineering based on an Irish model began in Australia in 1861 (about the time the Morrill Act was passing the U.S. Congress) at the University of Melbourne with a three-year Certificate of Civil Engineer (CE) program. Soon after the turn of the century four-year engineering programs at Melbourne and at the University of Sydney, together with a few diploma courses in technical colleges had begun to change the professional formation from the old pupilage [apprentice] mode to the education mode.

In 1919, when the Institution of Engineers, Australia was founded, some 57% of engineers had qualified through formal education, and by 1940 the proportion was 92%. The binary system of universities (4-year degrees) and technical colleges (3-year diplomas) continued until 1980, after which all engineers qualify from four-year or equivalent courses.[2]

Number and Types of Engineers. Figure 1, in which engineer populations are normalised to national populations, provides an indication of engineer density in each country. While the graph shows a trend in Australia to increase at a faster rate than the U.S., the engineer density there is still about 25 years behind that of the U.S. With 15 times the population of Australia, the U.S. has 22 times as many engineers. Table 1 shows this multiple varies from only 10 times as many civil engineers (reflecting the earlier stage of infrastructure development in Australia) to 15 times the mechanical engineers, 22 times the electrical engineers, and 48 times the engineers of "other" categories (reflecting the greater intensity and sophistication of manufacturing in the U.S.). It is estimated that the U.S. employs 51% of all engineers in manufacturing and Australia 24%.[3] This difference obviously has implications for the approach to education for engineering management.

ENGINEERING AND ENGINEERING MANAGEMENT PROFESSIONAL ORGANIZATIONS

United States. American engineers belong to a "crazy quilt" of over 200 national engineering organizations. These include societies based on a specific engineering discipline, on an occupational field, or on a specific material, technology, or force of nature. There are also associations of individuals or of other societies formed to accomplish some multidisciplinary purpose, such as the American Societies for Engineering Education (ASEE) and Engineering Management (ASEM), the National Society of Professional Engineers (NSPE), and the Accrediting Board for Engineering and Technology (ABET). Finally, the American Association of Engineering Societies (AAES) was formed to provide an "umbrella organization" of the disciplinary societies that could represent the profession as a whole, but some of the major societies do not participate and it enjoys only limited success.

Australia. The Institution of Engineers, Australia (IEAust) was formed in 1919 and exerts a decisive influence over the profession and its education. There was an early drive for registration of professional engineers, but that objective was not achieved. The Institution was incorporated by Royal Charter in 1938, providing a special identity and legal protection of value to the modern profession.

The Charter charges the Institution with promotion and advancement of the science and practice of engineering in all its disciplines for the whole of the profession in Australia. In fulfilling its obligations to the Australian community, IEAust: (1) co-ordinates private and public industry engineering practice with engineering education; (2) regulates the ethical practice; (3) conducts professional society activities; (4) fosters and conducts continuing education; (5) represents the profession to governments and internationally; and (6) delineates the profession and its support qualifications through accreditation of education and recognition of qualifications and experience.

Two other organisations contribute to the national regulation of engineering: the Association of Professional Engineers and Scientists, Australia (APESA), addressing the industrial relations of employee practice, and the Association of Consulting Engineers, Australia (ACEA), concerned with independent consulting practice.

As a national organisation serving all of the disciplines of engineering and many professional interests, the 60,000 member Institution has a complex matrix structure (Figure 2). The geographic dimension consists of the nine regional divisions.

0-7803-0854-9/92/$3.00 ©1992 IEEE

A second dimension, under a Board of Engineering, consists of four Colleges of (civil, chemical, electrical, or mechanical) Engineers and special interest societies (such as the Australian Association for Engineering Education (AAEE) and the Society for Engineering Management Australia (SEMA), founded in 1990. These two dimensions come together in branches or panels, which represent a discipline or special interest within a geographical region.

A Board of Education and Training deals with policy issues, and has subordinate boards governing accreditation of education and qualification of foreign-educated engineers. During 1990 the Institution established Engineering Education Australia Pty Ltd as a company to offer a variety of continuing education to its members. In 1990 it also gave substance to a systems view of the work force and its education through non-engineer membership for Engineering Technologists and Engineering Associates in two associated national Societies (Figure 2). This move contributes positively to greater flexibility and responsiveness to work-force needs.

International. The IEAust represents the Australian engineering profession internationally through affiliation with 22 bodies, including the World Federation of Engineering Organizations. Formal agreements of cooperation have been signed with a further 15 engineering societies in Britain, the U.S., China, Indonesia, Malaysia, Singapore, New Zealand, Japan, Papua New Guinea, and the USSR. The engineering bodies in Australia (IEAust), Britain, U.S. (ABET), Canada, Ireland, and New Zealand have an agreement for mutual recognition of professional engineering courses accredited within their countries. The existence of such an agreement provides the Australian profession with protection and enables the Institution to defend its position in regard to recognition of migrant engineers.

The formation of SEMA in 1990 provided the welcome opportunity for Australian engineers to participate in the creation of International Federation of Engineering Management Societies (IFEMS), which was formed jointly with the American and Canadian Societies for Engineering Management at a signing ceremony in the Australian embassy in Washington in January 1991.

ENGINEERS IN MANAGEMENT

United States. Engineering manpower data[4] from a 1969 survey showed that only 38% of young (25-30) U.S. engineers had supervisory or management responsibility, primarily first-line supervision of a project or section. However, over the last 2/3 of engineers' careers (ages 35-65), at least 2/3 of engineers held supervisory or management positions; from age 45 at least 40% of them managed a major division, program, or company. Until the last few years there has been little reason to believe these figures had changed. Recently many American industrial firms have been undergoing a "flattening" of their organization structure, eliminating large numbers of middle managers and transferring more responsibility to nonmanagerial members of self-managing teams. As a result, organizations will have to find ways to motivate engineers and other professionals for longer periods in nonmanagerial responsibilities.

Australia. Various surveys have estimated the managerial involvement of Australian engineers, although care needs to be taken with definitions. In 1971 a large survey showed 38% of engineers in supervision and management, and a further 12% in what were called 'non-engineering' roles, most probably in engineering organisations and requiring engineering backgrounds. Surveys in 1982 and 1989 show 33% in 'management and administration' and another 20% in 'other' roles.

Engineers in top management. Lawrence Grayson, recent president of the American Society for Engineering Education, reports that engineers are not achieving the top levels in American corporations in sufficient numbers:

> Engineers must be prepared for leadership - leadership in technical, corporate, and national affairs. More and more problems facing this country have strong technical components. Yet, engineers are not attaining the appropriate leadership positions and therefore have not been able to make the decisions that the nation requires.
>
> In France, most of the leaders of business and government have graduated from the elite Grands Écoles. These approximately 175 schools concentrate primarily on teaching engineering and technology. In West Germany, a majority of the corporate leaders are alumni of the technical universities, whose graduate engineers have completed a period in industry and a thesis on an industrial problem. In Japan, more than 65 percent of the members of the boards of directors of the nation's leading companies have graduated from engineering and science programs, not graduate schools of business.
>
> In contrast, roughly 2/3 of the seats on boards of American companies are occupied by people trained in law, finance, or accounting. Only 81 of the CEOs of the top American companies...were educated in engineering or science.[5]

As in the U.S., Australian enterprise structures have been flattened and many middle management people, including engineers, have been shed. This has been exacerbated by a tendency to 'de-engineer' many engineering leadership roles, especially in public sector enterprises, on the basis of a conventional wisdom that engineers are not good managers. There are worries within the profession that the leadership of the profession, both within enterprises and in professional societies, will suffer from these trends.[6] As in the U.S., there also is concern for the motivation of engineers, and for provision of parallel career pathways for specialist and practitioner engineers.

Many Australian engineers do attain top positions: several are, or have been, CEOs of major banks, companies and government enterprises and departments. The Chief of the Defence Force is an army engineer, and others hold field and specialist rank. Despite these facts, the representation of engineers in the boardrooms of the nation is nothing like as dense as in France, Germany, or Japan. A survey in 1990 of the boards of the top 50 Australian companies showed that 2/3 were qualified in law, finance, or accounting, while only 15% were qualified in engineering.

UNDERGRADUATE EDUCATION OF ENGINEERS FOR MANAGEMENT

Australia. In 1990 IEAust adopted a policy requiring undergraduate engineering programs to devote 10% to engineering management, as one of the yardsticks in accreditation of engineering courses. Although many engineering schools already comply, those who don't have until 1995 to adjust their courses. This Policy reflects a concensus concerning the all-pervading importance of management in engineering. It was confirmed in May 1991 at the Federal level at a meeting of the Prime Minister's Science Council, where IEAust was urged to bring full implementation forward in 1993.

The Policy provides guidance for designing the management components of courses, interpreted as: (1) skills in presentation, organisation, and direction of engineering ideas; (2) the principles for planning, organisation, direction, and control of people and resources; (3) the principles of economics, finance, law, marketing, and business required in engineering;

and (4) social responsibility in engineering, including professional responsibility and liability, social and environmental issues, and ethics of engineering practice. What is sought is a holistic approach, integrating management studies into the total course. While studies of 'management' that concentrate upon analytical and mathematical aspects will form part of the study structure, concentration on such aspects of management will not satisfy the policy. A wide range of studies is required in a balanced sequence.

United States. ABET criteria for an accredited (4-year) engineering curriculum specify at least one year of "an appropriate combination of mathematics and the basic sciences," one year of engineering sciences, and one-half year of engineering design. Of 17 "management" topics described in the Australian guidelines, only two (management science and operations management) fit within this specified 2.5-year content. ABET also requires one-half year of "humanities and social science," which can include economics but not "Subjects such as accounting, industrial management, finance, personnel administration, [or] engineering economy." Oral and written communication are considered important, but any separate coursework for the purpose of developing skills in this area (or in drafting or in computer programming) is not counted toward the three specified years of content. ABET has no objection to management content in an engineering program, but it competes with "skills" courses and other program objectives for the unspecified 25% of the curriculum. As a result, the American engineering graduate is fortunate if he has a single three semester hour course on the nonquantitative aspects of management, which form the bulk of the minimum ten percent of the new Australian curriculum.

GRADUATE EDUCATION OF ENGINEERS FOR MANAGEMENT

United States. About 23% of U.S. engineers hold the masters as their highest degree, and 4.3% the doctorate. To be ABET-accredited, a masters degree in engineering must comprise at least a year's (full time) study; at least 2/3 of this must be math, science, engineering science, or design, which leaves little room for management. The engineer interested in management may choose instead (or in addition) one of more than 400 M.B.A. programs offered by graduate schools of business. In the last 25 years the number of U.S. engineering schools offering degree programs in management tailored to the needs of the engineer has grown from a handful to over eighty. Most of these engineering management programs are part-time evening masters programs in urban settings.

Australia. Research in 1982 revealed a participation of only about 1.2% of the then 70,000 Australian engineers in postgraduate management education.[7] That situation has taken a dramatic turn.

In 1987 the Association of Professional Engineers and Scientists, Australia (APESA) began development of an educational program to provide access to management qualification of direct relevance to engineers, delivered through guided private study. The diploma, which uses special designed material and examinations produced and delivered with assistance from Deakin University, is accredited and nationally registered. The first intake in February 1989 consisted of 750 students from throughout Australia and nearby countries, and from 309 organizations. By spring 1991, 120 diplomas had been conferred. These numbers, high for Australian programs, indicate a widely-held realization of the need for education in management, and an appreciation of the mode of delivery. APESA now has 2,000 students, and has commenced offering an MBA (Technology Management) on top of the diploma.

In recent years the universities have introduced several master level programs in engineering management, and there are several graduate diploma programs. Engineers also participate in large numbers in the many MBA programs throughout the country.

Recent surveys indicate about 21% of Australian engineers hold postgraduate qualifications: from 2.5% to 4% doctorates and the rest graduate diplomas and master degrees. A 1988 APESA survey showed some 17% of engineers held higher education qualifications in a non-engineering field, including 9% in business or economics, 2/3 at postgraduate level. During 1991 APESA organised a significant research consultancy, with the support of IEAust and major employers, into the future needs of engineers for professional development. Apart from identified needs for keeping up with technology, a major finding was a plea for the grass roots of the profession for much improved education and professional development in engineering management.[8]

CONCLUSION

Australian engineering education lagged the United States in growth and in elimination of all but 4-year degree programs as the basis for professional qualification. They are about 25 years behind the American pattern in the concentration of engineers in the population and in manufacturing employment, but are catching up. Half or more Australian and American engineers move up to management positions, but the concentration of engineers in top management is far less in either country than it is in France, Germany, or Japan.

Over the last decade there has been a surge of interest in management education among Australian engineers. The self-help APESA diploma and MBA a direct response to the threat to career progression posed by the de-engineering of engineering leadership positions. The new "10% management" accreditation policy of IEAust helps assure that future graduates will experience a soundly based introduction to management during their undergraduate studies, and the foundation of SEMA provides recognition to the fact that the management of engineering is an indispensable part of engineering work.

BIBLIOGRAPHIC REFERENCES

1. Hoover, H.C. (1928) "The Engineer's Contribution to Modern Life," reprinted in The Profession of Engineer, New York, Wiley, 1929, p. 119ff.
2. Rice, M.R. and Lloyd, B.E. (1991) Professional Engineers in Australia: Projections of Supply, Melbourne, EPM Consulting Group.
3. Rice, M.R. and Lloyd, B.E. (1990) Professional Engineers in Australia: Population Analysis, Melbourne, EPM Consulting Group, compared with U.S. Census and Bureau of Labor Statistics data.
4. Engineering Manpower Bulletin 25, Engineers' Joint Council, New York, September 1973.
5. Grayson, L.T. (1989) "Education for Leadership," Engineering Education News, February 1989, p. 3.
6. Lloyd, B.E. (1991) Engineers in Australia: A Profession in Transition, Melbourne, Macmillan.
7. Stevenson, M. (1982) "Postgraduate Management Courses for Engineers: A National Survey," Proceedings of the First Australian Conference on Management Education for Engineers, Sydney, May 1982, pp. 75-80.
8. Bates, I.A., Lloyd, B.E., Martinelli, F., Stradling, J.B., and Vines, J., Skills for the Future, Engineers and Scientists Achieving Enterprise Performance, APESA, Melbourne, 1992.

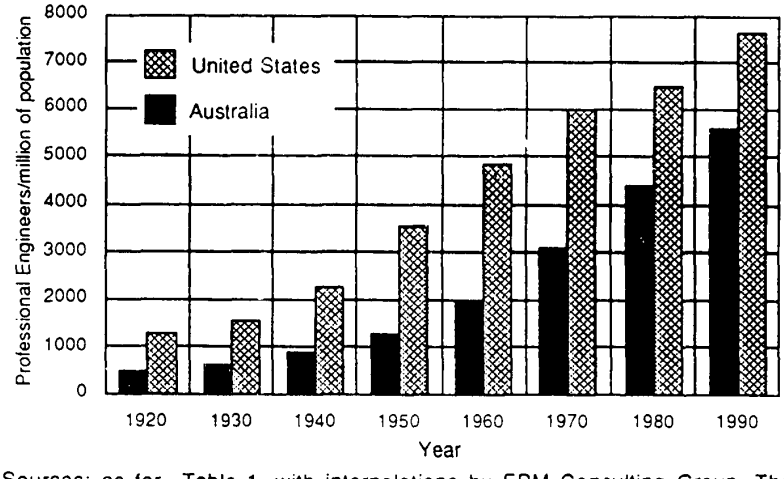
Dr. Daniel L. Babcock, P.E., is Professor Emeritus of Engineering Management at the University of Missouri-Rolla. He is executive director emeritus of the American Society for Engineering Management, a director of the new International Federation of Engineering Management Societies, and author of Managing Engineering and Technology (Prentice-Hall, 1991). In October 1991 he toured Australia as "Eminent Overseas Speaker" for the Institution of Engineers Australia.

Dr. Brian E. Lloyd, Chairman of the Society for Engineering Management Australia until 1992, is now President Elect of the Institution of Engineers, Australia. An electrical engineer and Director of the EPM Consulting Group in Melbourne, he consults in engineering education, management, and labour force analysis. He has published books on education, human resources, management, and Australian history.

TABLE 1
PROFESSIONAL ENGINEERS IN THE UNITED STATES AND AUSTRALIA
1920, 1960 AND 1990 - POPULATIONS AND DISTRIBUTION BY DISCIPLINE

	Civil		Electrical		Mechanical		Other		Totals
	Number	%	Number	%	Number	%	Number	%	
1920									
United States	56000	42	27000	20	39000	29	12000	9	134000
Australia	1250	50	625	25	475	19	150	6	2500
1960									
United States	158000	18	188000	22	162000	19	365000	42	871000
Australia	7400	37	5200	26	5600	28	1800	9	20000
1990									
United States	248000	13	593000	31	306000	16	765000	40	1912000
Australia	24000	27	28000	32	20000	23	16000	18	88000

Sources:
United States: 1900-1970 - Civilian employment of engineers, US Census Data (includes a proportion of unqualified people) ; 1990 - estimated by EPM Consulting Group, for qualified engineer population under 65 years, and with discipline distribution from Bureau of Labour Statistics 1988.
Australia: Rice, M. R. and Lloyd, B. E. Professional Engineers in Australia: Population Analysis, Melbourne, EPM Consulting Group, 1990. Figures are for total qualified engineer population under age 65 years, irrespective of employment.
Note that Electrical Engineering includes electronic and communication engineering.



Sources: as for Table 1, with interpolations by EPM Consulting Group. The discontinuity for the United States after 1970 reflects the different data sources, and a probable over-statement of engineer population in the Census by counting non-qualified people.

FIGURE 1
PROFESSIONAL ENGINEERS PER MILLION OF POPULATION IN THE UNITED STATES AND AUSTRALIA 1920 TO 1990

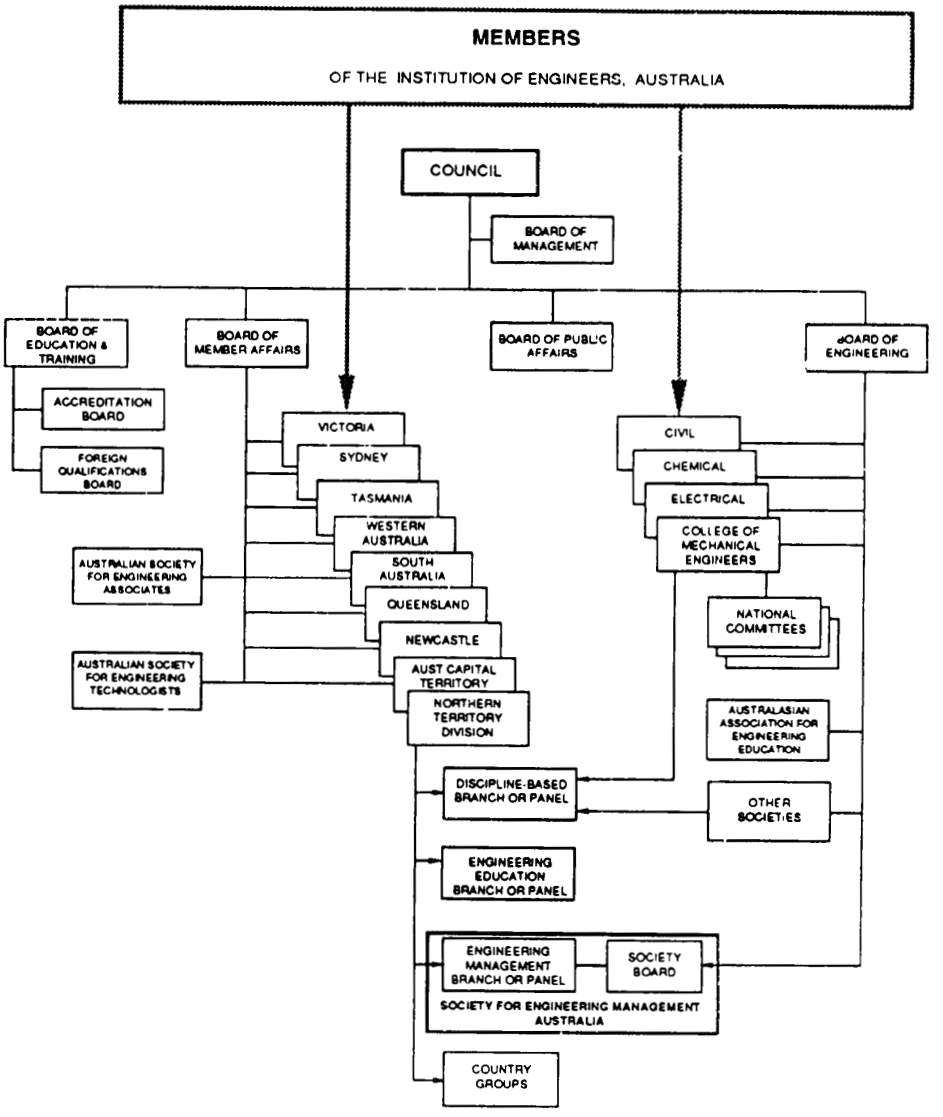


FIGURE 2 INSTITUTION OF ENGINEERS, AUSTRALIA SIMPLIFIED DIAGRAM SHOWING PROFESSIONAL SOCIETY UNITS WITHIN THE NATIONAL AND GEOGRAPHIC STRUCTURAL MATRIX