

*EVOLUTION
OF
ENGINEERING
EDUCATION
IN CANADA*



CANADIAN ACADEMY
OF ENGINEERING

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EVOLUTION OF ENGINEERING EDUCATION IN CANADA

A REPORT OF
THE CANADIAN ACADEMY OF ENGINEERING



Prepared by a task force chaired by
Dr. Arthur Heidebrecht, FCAE
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Canadian Academy of Engineering
130 Albert Street, Suite 1414
Ottawa, Ontario, K1P 5G4

Tel: (613) 235-9056 Fax: (613) 235-6861
E-mail: acadeng@ccpe.ca
Internet: www.acad-eng-gen.ca

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MISSION STATEMENT

The Canadian Academy of Engineering is an independent, self-governing and non-profit organization established in 1987 to serve the nation in matters of engineering concern. The Fellows of the Academy are professional engineers from all disciplines and are elected on the basis of their distinguished service and contribution to society, to the country and to the profession. The total number of Fellows at any one time may not exceed 250.

The Academy is self-financing and does not receive grants from governments although it may accept to carry out studies and surveys on a contract basis. The Fellows of the Academy can therefore bring into corporate activity, in a completely independent manner, the wide experience and expert knowledge which they have acquired as practicing members within the engineering profession of Canada, a profession now with 160,000 members.

The mission of the Canadian Academy of Engineering is to enhance, through the application and adaptation of science and engineering principles, the promotion of well-being and the creation of wealth in Canada.

The Academy fulfills this mission by:

- promoting increased awareness of the role of engineering in society,
- recognizing excellence in engineering contributions to the Canadian economy,
- advising on engineering education, research, development and innovation,
- promoting industrial competitiveness while preserving the environment in Canada and abroad,
- speaking out on issues relevant to engineering in Canada and abroad,
- developing and maintaining effective relations with other professional engineering organizations, academies and learned societies in Canada, and abroad.

ABSTRACT

Recognizing the changing role of engineering in society, the Canadian Academy of Engineering established a task force to make recommendations on the roles of engineering faculties. The report of the task force, while identifying a number of important roles, focuses on the further broadening of engineering education.

Its recommendations call for evolutionary changes to ensure that this broadening actually takes place through: ensuring that breadth of learning is a major thrust of engineering education, emphasizing the development of learning skills in engineering students and ensuring that faculty members have broadening-oriented vision, values and behaviour.

Engineering faculties should also participate in university-wide liberal education and in improving the technological literacy of the general public. The report also addresses the role of research in engineering faculties, particularly in relation to the life preparation of the graduate students. Implementation of the report's recommendations is a challenge for engineering deans and leaders in Canadian industry, business and government.

Evolution of Engineering Education in Canada

Executive Summary

In 1998 the Canadian Academy of Engineering established a Task Force to study and make recommendations on the roles in which Engineering Faculties are or should be involved. While a number of important roles were identified, this report focuses on education-related aspects and on establishing general directions for the future evolution of engineering education in Canada.

Engineering faculties in Canada have a fine record of accomplishments and have adapted well to rapid changes in science and technology in spite of a continuing environment of serious funding constraints. The new millennium presents them with increasing pressures and challenges arising from a broadening of the roles that engineers fill: in emerging engineering disciplines; in innovation and entrepreneurship; in international markets; in team leadership and interdisciplinary activity; and in protection of health, safety and the environment. Graduates of engineering faculties are needed to serve society not only in the traditional technical capacities which they need to master well but increasingly in non-technical leadership capacities.

The fundamental direction of this report is toward further broadening of engineering education. However, there is little flexibility to accommodate these pressures for broadening of the undergraduate curriculum and for incorporating the continual expansion of relevant technology within current time and resource constraints.

The report contains five recommendations which call for fundamental evolutionary changes to ensure that this broadening will actually take place:

- 1. Engineering faculties should ensure that breadth of learning, beyond the technical aspects of the specialist engineering discipline, is a major thrust in engineering education.***

The most important and fundamental role for engineering faculties is to prepare young people to work in various capacities in an evolving world, providing them with an education which is technically focused and has adequate breadth. Narrow specialization is not considered to be an appropriate response to expansion in technology. Society requires that engineering graduates be broadly educated, that they be knowledgeable about the society in which they live and work, that they be sensitive to the economic, social, political, environmental, cultural and ethical dimensions of their work.

The undergraduate curriculum should emphasize problem solving and design. Increased postgraduate opportunities and an emphasis on lifelong learning can provide both specialist information content and further broadening.

2. Engineering faculties should emphasize the development of the learning skills of their students.

A high priority should be placed on “learning how to learn.” Acquisition of the skills of self directed learning is important in preparing for life after leaving the university.

3. Leaders of engineering faculties should ensure that their faculty members have the vision, values and behaviours needed for their evolving role in preparing undergraduate and graduate students to function effectively in our rapidly changing world.

The desired broadening must take place largely within the engineering curriculum. It cannot be left to faculty in other parts of the university, to the more liberally minded engineering faculty members or to part-time faculty brought in to teach specific courses. It should permeate each component of the program. This requires active participation of professors in developing their own skills in education and in developing suitable educational experiences for their students. Access to specific preparation in teaching and learning pedagogy should be provided.

Criteria and practices on tenure and promotion must be such as to promote these broadening activities. Faculty must be assured that their efforts in these directions will enhance rather than impede their career progress.

4. Research conducted in engineering faculties should be characterized by excellence, by relevance to industrial and social issues and by concern for the life preparation of the graduate students involved.

Conducting quality research and design enhances the learning of both faculty and students and contributes to the innovation base for industry and society. Beyond the intrinsic value of the research results, there is a need for increased recognition of the value of the research experience to the professional development of the graduate students. Most employers will be primarily interested in the “people products” of graduate programs.

5. Engineering faculties should participate in providing liberal education opportunities for all university students, and in improving the technological literacy of the general public.

In a society which is so profoundly influenced by technology, the technological literacy of many university graduates is open to question. Engineering professors regularly deal with the interface between science and society and are in a position to contribute to liberal education of students and the public.

The Academy wants to see implementation of the directions charted in this report. The key players in implementation are the engineering deans who have direct responsibility for leadership in engineering education; and leaders in Canadian industry, business and government who have the responsibility to ensure that the importance of these directions to the health of the Canadian economy and society are fully appreciated and that the necessary resources are allocated.

Introduction

Throughout its history, the Academy has focussed on engineering education as the primary key to improvements in the service which the engineering profession provides for society. “Engineering Education in Canada” was the subject of an extensive report by the Academy in 1993¹. The Canadian Council of Professional Engineers and the National Council of Deans of Engineering and Applied Science produced an important report on engineering education in 1992². Also relevant to education were the Academy reports on *Lifelong Learning for Professional Engineers* in 1997³ and on *Wealth Through Technological Entrepreneurship* in 1998⁴. Valuable input from engineering students was presented in the report, *Feedback on Engineering Related Issues at the Canadian Congress of Engineering Students*.⁵ There is substantial agreement among these reports on general principles and many of the recommendations of these reports have been addressed by engineering faculties. However, implementation has been hampered by a number of factors many of which arise from a shortage of resources.

Accordingly, the Canadian Academy of Engineering established a Task Force in April 1998 to study the roles in which engineering faculties are or should be involved, and to make recommendations. These several roles relate to education of engineering students, contributions to useful knowledge through engineering research, interaction with industry in the design and development of new products and systems, contributions to the innovation and creation of new industry, education of other university students, continuing education of practising engineers and informing the public on issues of technology and its impact on society. There are many issues of immediate concern associated with these roles. While all of these roles are important, it became evident that adequate treatment of all could not be readily achieved in a single implementable report. It was then decided to focus the present report on education-related aspects, on establishing desirable general directions for the future evolution of engineering education in Canada and on measures to implement the necessary developments.

Engineering faculties in Canada enjoy a fine record of accomplishment both in the careers of their graduates and in their research contributions to engineering knowledge. Over the past decades they have adapted well to rapid changes in science and technology. However, the pressures and demands on these faculties

and on the present engineering curricula continue to grow. The time is opportune for a review of how these faculties should evolve to meet these extended demands.

Particular factors that lead to this review are:

- the broadened range of the roles that engineering graduates fill in society
- the rapid expansion of technology in the established engineering disciplines
- the emergence of new engineering disciplines such as bioengineering
- the high demand for graduates in the information technology industry
- the need for increased interaction of engineering professors with industry
- the need for more engineers with leadership capability in Canadian corporations
- the need for the creation of new technology-based enterprises in Canada
- the increased role which Canadian engineering plays in international markets
- the concern of society with matters of health, safety and environmental protection

The task faced by Canadian engineering faculties is a particularly daunting one in view of these increased demands coupled with the serious funding constraints that most of them have experienced in recent years. In spite of these constraints, notable progress has been achieved at many institutions providing models for future evolution. However, the flexibility of the engineering education system to respond to new demands is severely limited. It is not feasible to accommodate the pressures for broadening of the undergraduate curriculum and for incorporating the continual expansion of relevant technology within current time and resource constraints. Decisions among options for the evolution of the Canadian engineering education system over the next decade are needed if it is to respond adequately to the needs of our economy and our society.

The fundamental direction of this report is toward further broadening of engineering education. The recommendations of this report call for fundamental evolutionary changes in engineering education in Canada. These cultural changes are considered to be both desirable and necessary if engineering is to make its proper future contribution to the wealth and health of Canadian society and its environment. Many aspects of this evolution are already underway in Canadian engineering faculties but even with the enthusiastic involvement of engineering deans and professors these changes will not occur unless adequate resources are provided.

The Academy's objective has been to arrive at a set of principles and directions which will have the concurrence and support of both the Fellows of the Academy and the Engineering Deans. Reactions to early drafts of this report were obtained from a number of Engineering Deans, from several Academy Fellows in industry and from the Canadian Federation of Engineering Students. The report was

discussed at a meeting in May, 1999 with the National Council of Deans of Engineering and Applied Sciences providing further valuable input. A penultimate draft was prepared for discussion in the Annual General Meeting of the Academy in June, 1999. At that meeting, the Fellows unanimously endorsed the general principles of this report while providing additional input and recognizing that many matters of detail would have to be addressed in the process of implementation. This draft was sent to the Deans and input received has been incorporated into the report.

The Academy plans to mobilize the support of its Fellows together with that of leaders of industry to assist the engineering academic community in persuading governments, universities, industry, the engineering profession and the public of the need for these changes and in requesting from them the necessary resources.

Premises

The fundamental basis for the evolution of engineering education developed in this report arises from the definition of engineering adopted by the Canadian Academy of Engineering:

Engineering is a profession concerned with the creation of new and improved systems, processes and products to serve human needs. The central focus of engineering is design, an art entailing the exercise of ingenuity, imagination, knowledge, skill, discipline and judgement based on experience. The practice of professional engineering requires sensitivity to the physical potential of materials, to the logic of mathematics, to the constraints of human resources, physical resources and economics, to the minimization of risk, to the protection of the public and the environment.

Some of the basic premises for this report are:

- Graduates of engineering faculties are needed to serve society not only in the traditional technical capacities which they need to master well but increasingly in non-technical leadership capacities.
- The most important and fundamental role for engineering faculties is to prepare young people to work in these various capacities in an evolving world, providing them with an education which is technically focussed and has adequate breadth.
- Narrow specialization is not considered to be an appropriate response to expansion in technology.
- Conducting quality research to enhance the learning of both faculty and students and to contribute to the innovation base for industry and society is a very important role for engineering faculties.

- Engineering faculties are to be sensitive to the needs of their several stakeholders: students, faculty, the university, the engineering profession, industry, employers, society and governments.

Recommendations

1. Engineering faculties should ensure that breadth of learning, beyond the technical aspects of the specialist engineering discipline, is a major thrust in engineering education.

The tremendous growth of technology has resulted in pressure on engineering faculties to pack more and more technical content into their undergraduate engineering curricula. Also, engineering graduates are increasingly required to contribute in areas well beyond the technological dimensions. Modern society requires that engineering graduates be broadly educated, that they be knowledgeable about the society in which they live and work, that they be sensitive to the economic, social, political, environmental, cultural and ethical dimensions of their work. In Canada, there is a particular need for graduates with entrepreneurial skills to develop new enterprises on which future economic and social wealth depends⁴.

Employers of graduating engineers seek technologically-based, broadly-educated people with good oral and written communication skills, ability to work as part of a team, potential to take a leadership role, a basic knowledge of business and management and a sensitivity to the economic and social impact of engineering activity. Input from graduates after a few years of experience, particularly those in small industry, supports inclusion of emphasis on these factors in curricula.

Expansion of emphasis on these broadening aspects of engineering coupled with the continual expansion of technical knowledge requires a re-examination of the context in which Canadian engineers are educated.

Over the years the Canadian Engineering Accreditation Board has promoted the broadening of engineering curricula with its requirement that a minimum of one-eighth of the time in the four-year undergraduate curriculum be devoted to non-technical areas including course material on economics, communication and the social impact of technology. The emphasis given to these “complementary studies” and also their breadth and effectiveness are now considered to be insufficient to provide the quality of education which is required for many of the roles that engineering graduates are required to undertake. The issue goes well beyond the contact hours provided. It concerns the need for students to integrate these extended dimensions into their engineering activities, projects and

assignments. It concerns the need for students to study in an environment that develops inquiring minds and positive attitudes about these non-technological dimensions of their university education. Experience reported to the task force has shown that courses taken from elsewhere in the university may not produce the broadening that is desired. Rather, these broadening aspects need to be closely integrated into the approach to engineering problems and designs.

Many graduates of engineering programs enter areas such as finance, management, law and administration. As the broadening aspects of the engineering undergraduate experience are enhanced, engineering programs can become more attractive to students who wish to be broadly educated but who also recognize the importance in the modern world of a technological basis for such an education. This trend may be of particular importance in attracting more women to engineering.

One critical response to this recommendation will be that there is insufficient time in the normal four-year (or equivalent) undergraduate curriculum to be able to include more of these broadening aspects without sacrificing the technical competence of engineering graduates.

The pressure from expansion of technological knowledge has sometimes been met by increased specialization at the undergraduate level providing a sequence of technical courses intended to bring the student close to the discipline's state-of-the-art upon graduation. This approach is not considered to be appropriate for undergraduate engineering education.

A detailed solution to this time constraint issue is beyond the scope of this report but the following general approach is presented for discussion. It is proposed that four-year undergraduate engineering programs leading to a Bachelor's degree be retained with enhanced emphasis on breadth. Coupled with this would be a major expansion over the next decade of fifth-year programs leading to a professional Master's degree and expansion of other postgraduate opportunities.

The approach at the undergraduate stage would focus on identifying and teaching fundamental concepts and developing the skills of applying these to practical engineering problems. Emphasis would be placed on problem solving, on design, on project-based learning and on enhanced learning skills (considered in Recommendation 2). To quote the earlier Academy report¹, it is felt that such a program "can instill a set of concepts, attitudes, skills and habits that become the most important continuing attributes of an engineer." Many engineers report that they have forgotten much of the information content of their engineering programs but they insist that their continuing effectiveness is due in large measure to the set of skills and attitudes acquired during their undergraduate engineering education. The emphasis should be on process rather than information content.

The essence of engineering is design, a multi-disciplinary approach to meeting economic, social and environmental needs. It is in this context that broadening is interpreted in this report. Integrating the aspects of this broadening into the undergraduate curriculum requires intensive interaction of staff with students. It requires considerably greater resources than are currently provided. The undergraduate curriculum and experience should be based on the premise that all graduates will be involved in lifelong continuing education, some formal and some self directed, following the best practices outlined in the recent Academy report on lifelong learning³. Access to continuing education courses and workshops is important and engineering faculties should be encouraged to increase their participation in provision of these programs.

In the broader approach which is recommended for undergraduate programs there may be some reduction in specialist technical information content. This need not lead to a reduction in the real technical competence of the graduate. It is felt that, given the appropriate resources and effort, the proposed broadened programs can more fully meet the spirit of the profession's accreditation criteria than is currently feasible.

To compensate for a limitation on technical specialization at undergraduate level and to continue the broadening of the student, extended offerings of Professional Masters programs in engineering should be provided either on a full time or part time basis. Flexibility in access to such programs and cooperation among university engineering faculties should be encouraged. Integrated five-year dual degree programs may be advantageous for some students.

In the envisaged evolution it is expected that an increasing proportion of engineering graduates will acquire postgraduate degree qualifications in engineering or in related disciplines. For some graduates, the desirable option may be an integrated dual-degree program combining engineering and management. Some engineering graduates may be best served through integrated arrangements for entry to a related profession such as law, medicine or education. Valuable innovative experience has been acquired by several engineering faculties in Canada in promoting such programs.

Currently, the dominant formal postgraduate programs are those leading to research-oriented Masters and Doctoral degrees. While many graduates of these programs may continue to be employed in research roles, an increasing number are involved in industrial innovation and the creation of new enterprises. Their preparation for these roles can be enhanced by the broadening aspects of their undergraduate education and by inclusion of management and entrepreneurial concepts in their graduate studies.

Among the professions, engineering is unusual in requiring only a four-year (or

equivalent) formal undergraduate education plus relevant experience prior to professional registration. Considering the ever increasing breadth and complexity of engineering practise, it may now be appropriate for the engineering profession to reassess its requirements for entry to professional status.

2. Engineering faculties should emphasize the development of the learning skills of their students.

In planning the evolution toward a broader but still technologically-based education, a high priority should be placed on “learning how to learn.” The engineering student must certainly have developed a basic competence in a technical discipline by the time of graduation. But with technology changing so rapidly and the roles of engineers being so diverse, acquisition of the skills of self directed learning may be even more important as a preparation for life after leaving the university.

This capability for self-directed learning can be developed through assignments and projects which require the student to acquire new information, new analytical tools and new skills. Experience with project-based engineering education has been shown to produce graduates who are particularly well adapted for roles in small and medium industry. This approach is consistent with the emphasis on broadly-based design which should characterize engineering. However, it must be recognized that this approach requires intensive interpersonal contact between student and staff.

The learning skills acquired as an undergraduate can enhance the effectiveness of graduate studies and can contribute substantially to success in research programs.

Collaboration of professorial staff with industry can provide a source of student design projects which require initiative in the application of learning skills and may also provide useful results for the industrial sponsor. Industry has a responsibility to provide undergraduate students with opportunities for broadening engineering experience through cooperation in project development and through involvement in cooperative and internship employment.

There is great potential in using new information technology to assist in this learning process. The shift toward the development of and reliance on self directed learning coupled with ready computer access to desired information can be accompanied by somewhat less reliance on formal lectures. The role of the instructor can evolve from that of primary provider of information content to that of facilitator, coach and mentor. The objective in this is to improve the quality of the educational experience. Engineering is a professional faculty with special responsibilities for developing professional attitudes and habits.. The professorial time which is made available for this approach to education must be appropriate for this professional character.

3. Leaders of engineering faculties should ensure that their faculty members have the vision, values and behaviours needed for their evolving role in preparing undergraduate and graduate students to function effectively in our rapidly changing world.

The evolution toward a more broadly-based engineering education with greater reliance on the development of learning skills calls for a reexamination of the roles and preparation of engineering professors. This recommendation calls for recognition by the leaders in our engineering faculties that they are responsible for inculcating the appropriate attitudes, values and skills among engineering faculty members.

Broadening should be emphasized in all aspects of the engineering program. It can take place much more effectively in engineering classrooms than in unintegrated non-technical courses. The broadening cannot be left to faculty in other parts of the university, to the more liberally minded engineering faculty members or to part-time faculty brought in to teach specific courses. It should permeate each component of the program.

Engineering professors are normally appointed on the basis of having specialist knowledge in a field within one of the engineering disciplines. The usual evidence of that capability is a doctoral degree based largely on demonstration of potential for conducting original innovative research. This preparation is appropriate for the role of the professor as researcher and technical expert. It is not necessarily adequate to provide understanding of the broader aspects of professional engineering practice or to provide the range of skills which are increasingly required for effective education for students.

Recruitment of professors after some industrial experience is strongly preferred. All engineering faculties are encouraged to follow the lead of those schools that include this preference in their recruiting criteria. However, such recruitment from industry is not currently feasible in many instances. Competition among universities is fierce internationally for new staff in certain high demand areas such as computer and software engineering. Also, engineering schools are in salary competition with industry in these areas.

Just as engineering faculties in Canada have been able to recruit their undergraduate students from among the most highly qualified of high school graduates, those eventually recruited to professorial positions in engineering faculties, whether from graduate school or industry, are persons of superior quality; they are productive, conscientious and enthusiastic. They have great potential for development and for contribution to society. Given the appropriate incentives they will quickly acquire the skills desired for their evolving professorial roles.

Engineering faculties have a responsibility to provide the facilities, time, mentoring and guidance which will help these new professors to develop their specialized skills as broadly-based engineering educators. As the recommendations of this report are adopted, the educational environment will not be the same as it was when these persons were students and teaching assistants. They should be made aware of the objectives and goals adopted for broad technologically-based education by the engineering faculty and their commitment to these objectives and goals should be ensured. The achievement of these objectives can be assisted by providing these faculty members with access to specific preparation in teaching and learning pedagogy.

As noted before, the essence of engineering is the design of processes, products and services. If engineering professors are to lead students to a capability in this area, it is important that they understand the variety of issues, criteria and constraints involved in the design process. To build this understanding, it is important that professors have basic experience in the professional practice of engineering. This experience may not be adequately acquired before professorial appointment and should in any case be continuously renewed. It is important that professors be able to allocate a reasonable part of their time to practising their profession of engineering. This can include sabbatical leaves and short periods of practice in industry and consultancies with a range of clients.

University policies on tenure and promotion generally contain criteria on teaching and research with consideration given to creative professional practice. While it might appear that these policies are sufficiently flexible to provide adequate emphasis on teaching and professional practice, it is well known that published evidence of research accomplishment has historically been the most important consideration in most past decisions on professorial tenure and promotion. The current perception among many newly-appointed junior professors is that they must give highest priority to research during the typical five-year period leading to tenure decision.

The desirability of broadening engineering programs may be accepted by many young engineering professors but they may also have a justifiable concern as to whether efforts in this direction may jeopardize their careers. This broadening cannot be properly achieved without the active participation of these young professors in developing their own skills in education and in developing suitable educational experiences for their students. They must be assured that their efforts in promoting the broad design-based process will enhance their career progress.

Implementation of this transformation in the role of engineering professors may require a restructuring of the policies, and in particular the practices, of recruitment, appointment, tenure, promotion and reward for engineering professors. The

evaluation processes must measure and give balanced weight to performance and accomplishment in teaching and mentoring as well as in research, engineering design and creative professional practice.

It is important that the workload of engineering professors be such that adequate time can be devoted to the various roles of teaching, coaching, researching and professional interaction with the wider community. In particular, there must be time to plan and implement the recommended evolutionary changes. The staff complement in engineering should be appropriate for its role as a professional faculty. Considering the intensive nature of the proposed student-centred learning approach at undergraduate level coupled with expansion of the graduate level programs, a substantial increase in staff complement and facilities will be required.

4. Research conducted in engineering faculties should be characterized by excellence, by relevance to industrial and social issues and by concern for the life preparation of the graduate students involved.

Carrying out quality research is a very important function of a modern university. Through their research, faculty members contribute to the knowledge base on which our economy and our social structures increasingly depend. Through research, concepts are generated that can lead to the generation of new enterprises and new wealth. It is through research that professors maintain contact and establish their reputations with the world community of experts who share leading knowledge in their field. Such expertise is an important national resource.

Engineering faculties are particularly concerned with research which is motivated by and deals with industrial and societal issues. Research done in collaboration with industry and business is of particular importance for engineering. In Canada, some sectors of industry rely heavily on the results of university research because their own research capabilities are quite limited. The benefits of such collaboration are partly in the research results that the work brings to the user community but also in the opportunities for building linkages among graduate students, faculty and creative leaders in industry.

Most of the research conducted within our engineering faculties is done in conjunction with graduate students pursuing masters and doctoral degrees. The new knowledge produced in their research is important to society. However, there is a need for increased recognition by research supervisors, by graduate school administrators and by research granting agencies of the value which this research experience adds to the graduate students in preparation for their professional careers. While some industries may look to universities as a source of research knowledge, most employers will be primarily interested in the “people products” of graduate programs. However valuable the research results may be, engineering

faculty need to recognize that the educational development of their graduate students is a primary responsibility.

The research experience of a graduate student, particularly at the doctoral level, may be seen by some primarily as a preparation for an academic appointment or a position in an industrial research laboratory. Properly structured, it can also be an excellent phase of preparation for a career as a leader in industrial innovation and entrepreneurship⁴.

It is important that the interpretation of engineering research in engineering faculties and in research granting agencies include the intellectual challenge of advanced design in which a unique combination of knowledge and skill results in a new viable product or process. It is design which distinguishes engineering from science. It is an activity which is highly creative and demanding. The criteria and practices of engineering research granting agencies must be such as to promote involvement in broadly-based engineering design.

Effective linkage of engineering professors with industry and with the user community is essential in devising appropriate research and design assignments for engineering graduate students. Industry leaders should recognize that they have an important role in providing opportunity for interaction with engineering professors and their graduate students. Any investment that they make will be more than compensated in the quality and orientation of the persons that they recruit as well as the research and design results that they receive.

5. Engineering faculties should participate in providing the technological aspects of a liberal education for university students, and in improving the technological literacy of the general public.

Programs in the arts and science disciplines have traditionally been thought of as providing a broad liberal education. The trend has however been toward increased specialization, even at the Bachelor's level. Many universities today are characterized by strong but often narrow disciplinary concentrations of teaching and research. For many students these concentrations tend to act as "silos" in which breadth and true interdisciplinary learning is implicitly or explicitly discouraged. In a society which is so profoundly influenced by technology, the technological literacy of many university graduates is open to question.

Many engineering programs have developed a similar tendency for over-specialization at the undergraduate level as a response to the expansion of technological knowledge. This trend has been constrained to a limited extent by the professional accreditation requirements which call for allocating a portion of curriculum time to "complementary studies" including economics, communication skills and the social impact of technology.

Engineering faculties should take the initiative to assist in advancing the technological literacy of university students. In this technologically dominated world, every liberally educated person needs a basic framework for understanding how things work. Engineering professors can be in a preferred position for this role as they regularly deal with the interface between science and society. The learning opportunities provided by engineering faculty could include formal courses made available as electives, short courses or workshops on specific topics and the development of Internet based resource material which could be used as the basis for independent study.

Engineering faculties should join forces with their counterparts in arts and sciences in promoting the value of a broad truly-liberal undergraduate education and in enhancing two-way learning interactions between the students and staff of their respective faculties. The ability of engineers to work with and lead multi-disciplinary teams can be enhanced by the experience of such early university interactions.

For some students, an integrated program in arts and engineering may be desirable. There may be a particular advantage in collaboration between engineering and education faculties in the technological education of future school teachers.

Engineering faculties should also play a leading role in advancing the technological literacy of the public. It is important that society have an understanding of both technology and engineering and the role they play in the creation of new wealth and high quality employment, and in preserving public health and safety.

Efforts in this area may well enhance the willingness of the public and its governments to provide adequate resource support for universities.

Implementation

Writing and tabling a report may be a satisfying experience for its authors but the exercise is of little value unless the recommendations of the report are implemented. In the case of this report, the challenge to the Canadian Academy of Engineering is a particularly daunting one in that its resources in facilities and staff are minimal. The only resource that it can bring to bear is the experience, wisdom and influence of the Fellows of the Academy. Their emphasis must therefore be on encouraging effective action by those who have the opportunity and responsibility to act.

A staged process is envisaged for decision and implementation of this recommended evolution in engineering education. This process will involve interaction with and among a number of agencies.

As noted in the introduction, a penultimate draft of this report was discussed by

the Fellows of the Academy at their 1999 Annual Meeting. Those present unanimously endorsed the principles and directions of the report while recognizing that many matters of detail would have to be addressed in the process of implementation.

The same draft was provided to members of the National Council of Deans of Engineering and Applied Science with a request for further input from individual deans. Submissions received have been incorporated into this report.

It is recognized that several areas of interest and concern, particularly those relating to research and university-industry linkages, have not been addressed in the report. It is proposed that the Deans be asked to consider joining with the Academy in a task force to explore these areas.

Given the support of the Academy Fellows and the concurrence of Deans and former Deans, the next proposed step is to arrange approaches to a number of eminent leaders in Canadian industry and business to solicit their endorsement of the recommended evolution in engineering education. Prominent Fellows of the Academy and Deans of local engineering faculties should be involved in these approaches.

A consensus among engineering deans, industry leaders and the Academy will provide a powerful base for approaches to governments, universities and professional engineering bodies. Initially, the objective of these approaches should be to convince these agencies that the proposed evolution is needed for the future health of the engineering profession in Canada and for the health of Canadian economic and social development. Recognizing the provincial responsibility for education and the diversity of local regional and institutional needs, many of these approaches should be made jointly by representatives of the Academy, local engineering deans and appropriate industry leaders. If concurrence in the principles and directions of the envisaged evolution in engineering education can be achieved at these meetings, detailed planning for implementation and resource-needs assessment can be undertaken.

While much of the detailed planning must be done in each individual institution, there are undoubtedly many areas where a broad sharing of experience and views can be beneficial. A number of Canadian engineering faculties have made significant progress on various aspects of this evolution. Their leadership can facilitate developments throughout the country. It is proposed that small working groups be formed to report on topics such as best practices in project and design based learning, the development of learning skills, combined bachelors-professional masters programs, professorial recruitment criteria and reward structures, outcomes measurement and accreditation implications. Deans might be asked to nominate interested champions of the proposed changes from among their

professoriate as members of these working groups. Fellows of the Academy would assist as appropriate.

Implementation of this recommended evolution will require the support and encouragement of the engineering profession as represented by the Canadian Council of Professional Engineers and in particular its Canadian Engineering Accreditation Board. Through its accreditation criteria the profession has promoted an emphasis on design and a broadening of the engineering education process. Accordingly, it is hoped that the recommendations of this report will be seen by the profession as contributing to a natural evolution of its accreditation process. The report raises a number of issues which will need to be addressed:

With the recommended broadening of the undergraduate curriculum, can the four-year or equivalent program still be considered as sufficient to meet the formal academic requirements for entry to the profession?

With integration of the technical and non-technical components of the curriculum in lectures, laboratories, designs and projects, what are the processes by which an accreditation team can identify the adequacy of the results of the program?

How can the accreditation process best encourage the academic development of new emerging engineering disciplines?

It is proposed that representatives of the Academy meet with the Board, its parent Council and possibly with provincial councils for in-depth discussions of these issues.

The Engineering Institute of Canada through its several constituent societies should be asked to publicize the recommendations of this report among its members and to solicit endorsement for its principles.

A further stage of implementation should involve the Natural Sciences and Engineering Research Council whose funding policies and practices have considerable impact on professorial priorities. This Council is providing significant support for the proposed evolution through its recently introduced program of design professorships.

The recommendations for evolution contained in this report are believed to be consistent with the general principles presented by engineering students in their 1997 report⁵. It is proposed that the Academy maintain its continuing liaison with the Canadian Federation of Engineering Students during the implementation process.

References

- 1 *Engineering Education in Canadian Universities*, Canadian Academy of Engineering, Ottawa, August 1993
- 2 *The Future of Engineering Education in Canada*, Canadian Council of Professional Engineers and the National Council of Deans of Engineering and Applied Science, Ottawa, 1992
- 3 *Lifelong Learning for Professional Engineers*, Canadian Academy of Engineering, Ottawa, October 1997
- 4 *Wealth Through Technological Entrepreneurship*, Canadian Academy of Engineering, Ottawa, March 1998
- 5 *Feedback on Engineering Related Issues at the Canadian Congress of Engineering Students*, Canadian Federation of Engineering Students, May, 1997

Task force composition

Arthur Heidebrecht,	Professor Emeritus (former Dean of Engineering and Provost/Vice-President, Academic) — McMaster University (Chair/Convenor)
Gordon Slemon,	Professor Emeritus (former Dean of Engineering) — University of Toronto (Editor)
Douglas Barber,	President & CEO — Genum Corporation
André Bazergui,	Special Consultant to the CEO, Innovitech Inc. (Professor Emeritus and former Directeur Général — École Polytechnique de Montréal)
Michael Charles,	Dean of Engineering, University of Toronto
Edmund Kuffel,	Professor Emeritus (former Dean of Engineering) — University of Manitoba
David Lynch,	Dean of Engineering — University of Alberta
Mohan Mathur,	Dean of Engineering — University of Western Ontario
Ronald McCullough,	President — KlasTech Ltd
John McDougall,	Managing Director & CEO — Alberta Research Council
Edward Rhodes,	President — Technical University of Nova Scotia
Frank Wilson,	Professor Emeritus (former Dean of Engineering and Vice-President for Research & International Cooperation) — University of New Brunswick