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Accreditation of a Mechanical Engineering Program*

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The paper describes the accreditation process of a mechanical engineering department in Canada, including the requirements that must be met to meet accreditation. The present system is examined, including some of its problems. A proposal is made to establish ISO criteria for accreditation; and hence establish a standard to which engineering departments can work

1. INTRODUCTION

IN THE increasingly prevalent 'global village' environment, engineers are highly mobile and often must practice their profession in a country other than where they were trained. Often an engineer is confronted with the prospect of having to meet accreditation requirements of the country in which he/she plans to work, especially if they wish to be called engineers or plan to work in an environment that requires them to belong to a local professional engineering organization.

In Canada situations arise where someone trained outside Canada will often have to write special exams set up by the Canadian Council of Professional Engineers (CCPE). The CCPE was established in 1936 as a federation of provincial and territorial authorities that licence engineers and oversee the profession across Canada. Because responsibility of accreditation lies with each individual province, of which there are ten, the CCPE does not have jurisdiction over the provincial registration committees or boards of examiners but extends full co-operation and assistance to them. The CCPE has members from each professional engineering organization in each province, e.g. the PEO (Professional Engineers of Ontario) or the APENB (Association of Professional Engineers of New Brunswick).

Canadian engineering students do not have to sit the CCPE examination so long as they graduate from a Canadian University that has been accredited by the Canadian Engineering Accreditation Board (CEAB). In 1965 the CCPE established the Canadian Accreditation Board, now known as the CEAB. The concept of accreditation was implemented by the profession to test and evaluate the undergraduate degree programs offered at Canadian universities and to award recognition to programs which meet the required standards. With the help of the provincial professional engineering associations, the CEAB was empowered to develop a minimum criteria for undergraduate engineering degree programs and, through a process of direct investigation, to provide engineering schools with a means to have their programs formally tested against these criteria [1].

If a university has been accredited, then the examinations given by the university are, in effect, used in place of the CCPE examinations. Obviously, all Canadian faculties of engineering strive to meet the CEAB requirements so that their students do not have to go through another set of exams in order to gain professional engineering status. A university that is not accredited would be at a severe disadvantage in attracting undergraduate students. Each department in a faculty of engineering must be accredited every six years by the CEAB. This is a time-consuming exercise and this paper describes the recent accreditation of a typical mechanical engineering department in Canada, including the rquirements for accreditation.

2. CEAB

The CEAB [1] is composed of 13 professional engineers drawn from private, public and academic sectors. The members are volunteers and represent different parts of the country as well as a wide range of engineering disciplines. The CEAB also relies heavily on the volunteer services of an extensive network of professional engineers who serve on visiting teams and other committees.

The CEAB publishes guidelines once a year [1] and revises these on a yearly basis. However, the guidelines are of a general nature and do not give specific details regarding course content.

2.1 *Accreditation visit*

An accreditation visit is undertaken at the invitation of an institution, usually a faculty of engineering with the agreement of the association that has jurisdiction in that province. A team of senior engineers is assembled consisting of a chair,

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specialists for each program to be assessed, and one or more engineers who represent the provincial engineering association. Armed with documents, including a detailed questionnaire completed beforehand by the institution, the team proceeds to consult with administrative staff, faculty, students and department personnel. Each member of the team has the responsibility for a department, mechanical engineering in our case.

The team examines the academic and professional quality of the faculty, adequacy of laboratories, equipment, computer facilities and more. This is done by one person per department. They also evaluate the quality of the students' work on the basis of face-to-face interviews with senior students, assessment of recent examination papers, laboratory work, reports and theses, records, models or equipment constructed by the students and other evidence of the scope of their education.

Furthermore, the team performs a qualitative and quantitative analysis of the curriculum content to ensure it meets the minimum criteria. The team then reports its findings to the CEAB, which then makes an accreditation decision. Accreditation, when given, is usually for six years.

As with the CCPE, the CEAB does not have jurisdiction over the provincial organizations but extends full co-operation and assistance to them. Since its inception in 1965 this arrangement has worked very well.

3. CURRICULUM CONTENT

Analysis of the curriculum content for a program forms the heart of the final assessment. Bachelor's degrees in Canada require a minimum of four years to complete at a Canadian university. In those four years the curriculum content must assure a foundation in mathematics, basic sciences, a broad preparation in engineering sciences and engineering design, and exposure to non-technical subjects that complement the technical aspects of the curriculum.

To satisfy accreditation requirements, an engineering program must include the following components of curriculum content:

- *Mathematics*: a minimum of one half year of mathematics including appropriate elements of matrix algebra, differential and integral calculus, differential equations, probability, statistical and numerical analysis. This amounts to one-eighth of a student's program.
- *Basic sciences*: A minimum of one half year (one-eighth of a program) of basic (natural) sciences, defined as appropriate elements of physics and chemistry and, where appropriate, elements of life sciences and earth sciences. These subjects are intended to impart an understanding of natural phenomena and relationships through the use of analytical and/or experimental techniques.
- *Engineering sciences and engineering design*: A minimum of two years (one-half of the program) of a combination of engineering sciences and engineering design is required. Within this two-year combination, either of engineering sciences or engineering design may not be less than one-half year (one-eighth of the program) and any combination of engineering science and engineering design may be given to give the two-year minimum for both.

Engineering design (ED) integrates mathematics, the basic sciences, engineering sciences and complementary studies in developing elements, systems and processes to meet specified needs.

Engineering science (ES) subjects normally have their roots in mathematics and basic sciences, but carry knowledge further toward creative applications. They may involve the development of mathematical or numerical techniques, modelling, simulation and experimental procedures. Application to the identification and solution of practical engineering problems is stressed. Subjects include strength of materials, fluid mechanics, thermodynamics, electrical and electronic circuits, materials science, computer science, automatic control, aerodynamics, transport phenomena and other subjects.

Appropriate content requiring the application of computers must be included in this component of the curriculum.

- *Complementary studies*: A minimum of one half year is required in management, engineering economics, communication, humanities, social sciences and arts. Considerable latitude is provided in the choice of suitable materials for complementary studies; however, some areas are considered essential to the education of an engineer. Therefore the curriculum must include studies in engineering economics and the impact of technology on society. Also provision must be made to develop each student's capability to communicate adequately, both orally and in writing. Language studies may be included but cannot be substituted for subject matter that deals with central issues, methodologies and thought processes of the humanities and social sciences.

The foregoing components must include the following in the curriculum content:

- Appropriate laboratory experience.
- Exposure to public and worker safety.
- Preparing students to learn independently.
- Exposure to engineering research and development.
- Exposure to innovative engineering activities.

Using the above, the minimum CEAB requirements can be abbreviated as shown in Table 1. The total minimum requirement is four years overall; for ES + ED it is two years. Then if ES = 0.5, ED has a minimum requirement of 1.5. The total for

Table 1. CEAB Minimum Requirements						
	Math	Basic Science	Comp. Studies	Eng'g Science [ES]	Eng'g Design [ED]	ES+ED
Years of Study	0.5	0.5	0.5	0.5	0.5	2.0

Table 1 is 3.5 years, which means that a program has an additional one half year which may be allocated to any specific areas it may want to emphasise.

4. TIME REQUIREMENTS

In assessing the time assigned to various components of the curriculum, one year is taken to consist of 26 weeks of instruction, excluding examinations. A reference program of four years' duration is assumed. In most programs the minimum duration is four years and the maximum allowable is six years.

It is important to note that most students must work during the summer months, from May to August inclusive, so that they can earn enough money to continue their education and also to enable them to obtain work experience.

5. PROGRAM ENVIRONMENT

Emphasis is placed on qualitative evaluation of the program and the overall environment in which the program is presented. Central importance is attached to the quality of the educational experience as reflected by the quality of the students, the faculty, the support staff, the administration, the laboratories, the library, the computing facilities and other facilities.

The character of the educational experience is influenced strongly by the engineering competence and outlook of the faculty. The faculty devoted to the program must be large enough to cover, by experience and interest, all of the curricular areas of the program. There must also be adequate levels of student–faculty interaction, student curricular counselling and faculty participation in the development, control and administration of the curriculum. Faculty teaching loads should also allow time for adequate participation in research and professional development activities. The engineering faculty must assume the responsibility of assuring that students receive proper curricular and career counselling.

The overall competence of the faculty is judged by such factors as the level of academic education on its members, the diversity of their backgrounds, the nature and extent of their non-academic experience, their ability to communicate effectively, their experience in teaching and research, their level of scholarship as shown by scientific and professional publications, and their degree of participation in professional, scientific and learned societies. A majority of faculty is expected to be registered as professional engineers.

In most Canadian universities the engineering faculty come from diverse backgrounds and educational systems. For instance, in one mechanical engineering department there are 25 faculty, ten of whom did their undergraduate degrees outside Canada: four are from Britain, and one from each of the following countries, France, The Netherlands, Poland, South Africa, Switzerland and the former Yugoslavia. This gives an added dimension to a recognition of what is needed in our curriculum *vis-à-vis* other countries. In addition, 23 have Ph.D.s from a variety of degree-granting institutions in North America and Europe.

6. SPECIFIC COURSE CONTENT

The specific content requirements for a mechanical engineering program cannot be found in the CEAB guidelines; however, they can be found in the CCPE examination syllabus [2]. For mechanical engineering the CCPE requires nine specific areas, of which the following six are compulsory areas: applied thermodynamics and heat transfer; fluid mechanics and applications; kinematics and dynamics of machines; advanced strength of materials; design and manufacture of machine elements; and electrical and electronics engineering.

Three additional areas are required and may be chosen from one of the following: advanced machine design; environmental control in buildings, energy conversion and power generation; systems analysis and controls; production planning and manufacturing; fluid machinery; aerodynamics, aircraft materials and structures; and finite element analysis.

Each of these areas is broken down into more specific detail. As a brief example, the details of only one will be listed, kinematics and dynamics of machines. *Kinematic and dynamic analysis*: graphical and analytical methods for kinematic analysis of space mechanisms and elementary body motion in space; static and dynamic force analysis of mechanisms; gyroscopic forces; dynamics of reciprocating and rotating machinery; balance of machines; cam and gear mechanisms. *Vibration analysis*: free and forced vibration of underdamped lumped systems with multidegrees of freedom; analytical and numerical techniques of solution; viscous damping; vibration isolation; vibration measurement and control; vibration of continuous systems.

It is obvious that given the time and resources required that the foregoing is given in a set of courses which, when put together, satisfy all the above requirements listed. In this case the six courses which cover all the detail listed above are: kinematics and dynamics of machinery [36 lecture hours], dynamics I (particle dynamics) [36 lecture hours], dynamics II (dynamics of rigid bodies) [36 lecture hours], machine design I (design of machine elements) [36 lecture hours], numerical methods for mechanical engineers [36 lecture hours], and vibrations [36 lecture hours]. Note: these hours are specific to our university and may be different at others.

As already shown, the required components in a program are mathematics, basic science, complementary studies, engineering science and engineering design. One of the courses listed above may have more than one of the compulsory components. To be able to quantify the weighting, load units are used, where a load unit is a measure of the number of lecture/laboratory/tutorial hours spent on course content. For instance, if a course has a total of 12 load units of which two are mathematics, this indicates 6 hr [$(2/12) \times 36$ hr] have been spent on mathematics or 16.7% of the course has mathematical content. These are defined as follows: 12 lecture hr equal 3 load units, 12 laboratory hr equal 1 load unit, 12 tutorial hr equal 1 load unit. Note: these are loading definitions used at Queen's and may be different at each university.

An example of second year loading is given in Table 2. One table is produced for each of the four years of compulsory courses in the program plus a table for technical electives in the fourth year. For the sake of brevity only one year is shown.

Table 2 shows that a course can have loadings in more than one area. The loading designation is the responsibility of the instructor. Consider kinematics of machines, for instance: there are 36 lecture hr and 24 laboratory hr, the course load total is 11 units, of which 2 are mathematics, 7 engineering science and 2 are engineering design. The 2 units of mathematics are for the time spent on complex numbers which are used in part of the course for analyzing planar kinematic motion. Two units are allocated to design because a considerable amount of time is spent on design and building a useful mechanism which is submitted at the end of the course. The totals for all courses are then summarized as shown in Table 3.

The most important parts of Table 3 are rows B and C, and columns 8–13. Recall that row C of Table 3 shows the minimum CEAB requirements for each area as indicated in Table 1. Row B shows if the institution meets the CEAB minimum requirement for each group. For instance, for mathematics content the calculation is 63 load units divided by the total load units of 495 times the number of years in the program. This gives 0.51, which is above the minimum of 0.5 required by the CEAB; in other words cell B8 $\geqslant$ C8. The com-

Table 2. Compulsory courses. Program: Mechanical Engineering, second year

Term of Year	Title (* F▲fall, W▲winter)	HOURS Lect	Lab /tut	Course Total	LOAD UNITS Math	Basic Science	Comp Studies	Eng'g Science	Eng'g Design	ES +ED
W*	Basic Electric Circuits	36	0	9	0	2	0	7	0	7
F	Ordinary Differential Equations	36	12	10	10	0	0	0	0	0
F	Manufacturing Methods	36	0	9	0	0	0	0	9	9
F	Kinematics of Machines	36	24	11	2	0	0	7	2	9
F	Mechanics of Solids I	24	12	7	0	3	0	4	0	4
W	Mechanics of Solids II	24	24	8	0	3	0	5	0	5
W	Dynamics I	36	12	10	0	0	0	10	0	10
W	Thermodynamics I	36	12	10	0	8	0	2	0	2
F	Fluid Mechanics I	24	12	7	0	4	0	3	0	3
W	Numerical Methods for Mechanical Engineers	36	24	11	11	0	0	0	0	0
F	Mechanical Laboratory I	0	24	2	0	0	0	1	1	2
W	Mechanical Laboratory II	24	60	11	0	0	0	11	0	11
F	Materials Science for Mechanical Engineers	36	0	9	0	4	0	4	1	5
FW	Economics	72	0	18	0	0	18	0	0	0
	TOTAL FOR TABLE 2 [second year]	456	216	132	23	24	18	54	13	67
	TOTAL FOR [first Year]	384	270	119	29	40	10	32	8	40
	TOTAL FOR [first and second year]	840	486	251	52	64	28	86	21	107

Table 3. Summary of all tables.											Program: Mechanical Engineering
SECTION	CATEGORY	ITEM	HOURS			LOAD UNITS					
1.	2.	3.	4. Lect	5. Lab /tut	7. Course Totals	8. Math	9. Basic Science	10. Comp Studies	11. Eng'g Science	12. Eng'g Design	13. ES+ ED
A	Hours/load units taken at the institution	Compulsory Courses (Totals from Tables)	1416	888	442	63	65	73	167	74	241
		Elective Courses (Totals from Tables)	180	372	53	0	0	0	0	5	19
		TOTAL	1596	1260	495	63	65	73	167	79	260
B	Years of study	This program - This option			4	0.51	0.53	0.59	1.3	0.64	2.10
C	Minimum requirements	Years of Study				0.5	0.5	0.5	0.5	0.5	2.0

parisons in this table must be made by column. The rows do not add up because of a calculation that occurs in a previous table for technical electives where a 'minimum path' that can be followed by any one individual student is calculated.

Table 3 is a typical example of a summary table; it is at the end of the curriculum analysis and is the most critical one in the report submitted to the CEAB. If the minimum requirements are not met, good reasons must be provided, otherwise a program risks losing its accreditation.

7. WRITTEN SUBMISSION

The foregoing is but part of the overall submission. The index of the submission gives a fair idea of what is contained in a typical submission which can be about 180 pages long. The following is an example of the contents:

- Program name: calendar, type of diploma, title appearing on transcript.
- Administrator responsible for the program.
- Program administration: a list of those involved in the program administration.
- Program objectives.
- Curriculum control: includes a list of faculty who are registered professional engineers.
- Student curriculum counselling.
- Complementary studies.
- Techniques of professional development.
- Design experience.
- Computing facilities.
- Computer experience.
- Shop facilities.
- Laboratory facilities.
- Laboratory experience.
- Imparting information about safety and health concerns.
- Engineering sciences.
- Faculty teaching loads.
- Teaching assistants; usually graduate students.
- Average completion time/attrition rates.
- Transcript analysis; ten student transcripts are chosen at random.
- Self-appraisal and objectives.
- Problems; as perceived by the department.
- Courses which are offered.
- Planning estimates; expected and planned student enrolment.
- Tabular information: personnel, full-time faculty, enrolment and degrees granted.
- Expenditures: operating, equipment, capital.
- Ratios: faculty/student/support staff.
- Analysis of curriculum content: tables for each year as shown in Tables 2 and 3.
- Course information sheets. A separate information sheet for each course.
- Individual, two-page curriculum vitae for each member of faculty.

From this list it can be seen that the program report is a very comprehensive document.

8. ACCREDITATION REVIEW RESULTS: SOME EXAMPLES

Accreditation reviews occur once a year somewhere in Canada because there are 29 degree-granting faculties in the country. As a result the review process is continually changing and when a department receives accreditation for six years, the guidelines may have changed when the review process occurs again six years later. This can provide some problems; for instance, say the percentage of faculty registered as professional engineers needs to be higher than previously required. Either some of the faculty then have to become registered professional engineers, something which has happened in the past, or if faculty positions are becoming available, then one of the requirements for hiring could be professional engineering registration.

In a recent accreditation review of an engineering faculty that has ten departments, five of the departments received accreditation for only three years instead of six because there were not enough professional engineering faculty teaching the students in those departments. These departments now have three years to address this problem.

In another case a department was found to have too little engineering design content and was given just one year in which to change their loading before accreditation was given. They altered their curriculum so as to meet the concerns of the CEAB and were given accreditation for six years, one year later.

Our department recently received accreditation for another six years, without any concerns being raised. However, in the report submitted to the CEAB [3] we had to address a criticism from our accreditation six years earlier. In the previous accreditation the committee said: 'the CEAB considers that provision to develop the students' ability to communicate verbally is only marginally adequate. Due consideration should be given to improving the program in this respect.' This problem was addressed in the self-appraisal section of the report, in which improvements had been made to the curriculum to increase verbal communication content in the curriculum. The CEAB also praises a program when it is appropriate; in our case they found that we gave our students excellent exposure to machine shop and manufacturing techniques through our laboratory/manufacturing program.

9. PROBLEMS

Obviously the accreditation system described is not perfect and has some failings. The first problem that occurs is the weighting of course content as discussed above and shown in tables 1 and 3. The problem is that a department is required to provide a minimum of say $\frac{1}{2}$ year, or $\frac{1}{8}$ year of the program on mathematics. This does not specify the number of minimum hours, and therefore a department may meet all the minimum requirements of the CEAB and then decide to increase the mathematical content substantially, leaving the other units as before. This then creates an imbalance so that other areas may not meet the minimum criteria, just because the department has decided to enrich their program with additional mathematics. As a result a department could work towards an absolute bare minimum and yet come up to CEAB standards. At the moment this problem does not arise because the visiting CEAB committee for each accreditation is comprised of a mix of individuals which contains academics from other institutions who know how this system works and who make sure that an adequate number of hours of a particular area are covered in order to meet the bare minimum. However the institution that wishes to enrich their students' education in a particular area is obviously penalized or the workload across all subject areas must be increased, which may not be necessary or desirable. This problem could be circumvented simply by insisting upon a minimum number of hours of instruction in mathematics, for instance.

Another problem occurs with the site visit as described in Section 2.1. Only one member from each team visits the site. This places great time constraints upon that individual over a period of two days. For instance he/she usually only has a couple of hours at most to check through all the details for each course which are all assembled in one room. This is an onerous, time-consuming task for one individual in such a short timeframe. This part of the assessment could be improved by having course details sent to the CEAB representative, who could then send details of each course to an individual working in that subject area. However, this would be a fairly cumbersome process.

The person representing the CEAB may have a bias towards a particular area or insist that certain equipment be in place when it is unnecessary. For instance, in the opinion of the visitor there may not be enough computer workstations available to undergraduates, whereas the members of the department may argue the opposite. The bias of the visitor can cast a negative shadow on the true intent of the accreditation process, namely to be sure that students are being educated in the basics.

CEAB guidelines regarding specific course content do not exist; one is driven to find other course content guidelines such as those of the CCPE to find specific course content requirements. This can be a problem when discussions about specific course content arise and for those responsible for a program or a particular course. The CEAB should provide more specific details in this area.

The comparison in Table 3 must be made by column, and as mentioned before the rows do not add up because of a calculation that occurs in a previous table for technical electives where a 'minimum path' that can be followed by any one individual student is calculated. The calculation of a so-called minimum path is often confusing and tends to skew the final numbers so that the rows, row B for instance, do not add up as one might expect. In any adaptation of this system it would be a good idea to steer clear of this way of accounting for technical electives in the program.

10. ISO ACCREDITATION

Engineers live in an increasingly global village; they are highly mobile and often practice their profession in a country other than where they were trained. The engineering environments they now work in are usually very similar and often require them to belong to a local professional engineering organization. The next logical step is to set up a minimum international standard. The ISO can provide such a vehicle. Although ISO standards are not compulsory, there is often pressure to meet their requirements, e.g. ISO 9000. The argument can be made that with the increasing mobility of engineers providing services in countries other than where their education occurred, there is a need for a standard against which a program can be measured.

There is also an advantage to this for graduate schools. Often foreign students apply to graduate schools in foreign countries and are confronted with the problem of satisfying a graduate school that they have met all the undergraduate criteria for entrance into a particular program. Part of the concern could be met if departments were to work to a minimum standard which could be set by the ISO.

So how can this be done? The answer lies in the question: how is any standard set up? In this case, many ISO contributors are academics and they could be polled to see if they are interested in participating in setting up an educational accreditation standard. Also, within the EU there will be similar groups with concerns that engineers from different countries in the EU meet a minimum standard; perhaps this process could start there. There are many ways of doing this and I shall leave it to others to reflect upon how this could be done.

11. CONCLUSION

The foregoing shows part of the process of accreditation required of all Canadian engineering programs, with a specific example of a mechanical engineering program; other programs are accredited similarly. The reporting format used is quite comprehensive, has been operating successfully for a considerable time, since 1965, and could easily be used as a starting model for international standards. Although there are problems with the CEAB accreditation process, these can be addressed. Increasingly, and for the better, many universities are establishing arrangements and agreements with institutions in other countries [1]. This interaction shows the need for an international standard toward which programs can work.

There are agencies which write reports about engineering education in other countries that can sometimes be misleading. For instance, in reference [4] it is reported, in the context of technical education, that Canadian universities are not accredited, whereas in fact all approved engineering programs in Canada have gone through a rigorous accreditation process every six years since 1965. How many other misconceptions do we have about each other?

There is an opportunity to set a world minimum standard, and an ISO standard would provide a method of ensuring a program meets that minimum standard. This paper proposes a group be set up to create a minimum standard to which those responsible for a program can work. It must be noted that ISO accreditation would not be compulsory but purely voluntary, as is ISO 9000, a standard which many industries are trying to meet without being forced to do so.

REFERENCES

1. Canadian Engineering Accreditation Board (CEAB), 1992 Annual Report, CEAB92-06-30. CCPE 401-116 Albert Street, Ottawa, Ontario, Canada.
2. CCPE examination syllabus (1992).
3. 1993 Report to Canadian Engineering Accreditation Board (CEAB), Part 2, Mechanical Engineering, Queen's University.
4. R&D in Canada, p. 13. Technieuws Ottawa, Ministry of Economic Affairs, The Hague, ref. no. 0I-87-01 (May 1987).

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