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Canadian Approach to Global Evaluation of Engineering Education and Services*

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A brief discussion of the Canadian procedures for accreditation of engineering programs is presented initially and its most important features are highlighted. The importance of these requirements is discussed from the perspective of substantial equivalency and a global acceptability of various approaches to engineering education by various countries while maintaining achievable objectives. The current international efforts for globalization of engineering trades and services are reviewed and the requirements for the development of efficient multilateral agreements are discussed. Finally, the current plan of CCPE International Affairs to develop bilateral and multilateral agreements covering engineering accreditation, licensure and practice is presented and discussed from an international perspective.

INTRODUCTION

THERE IS NO doubt that the engineering profession, like most of the other universal professions, is going to be submitted to global evaluation, both in terms of the qualities that a universally accepted engineer should have from an educational point of view and also as an acceptable provider of professional services in any jurisdiction. Of course, there is still a long way to go before such an eventuality is realized but there are many discussions, agreements and accords that bring this ultimate requirement closer and closer.

Dealing with many countries having various legal frameworks, requirements, local codes and procedures to govern the practice of engineering makes it an enormous task to define specific rules for each case to be considered. The similarities and differences between countries that want to enter bi- or multilateral agreements must therefore be quantified using references that allow flexibility and judgment without sacrificing the rigorous appreciation of all the important elements.

The purpose of this paper is to detail the way the Canadian Council of Professional Engineers (CCPE) deals with the various aspects of the global evaluation of engineering education and practice, particularly the substantial equivalency of engineering programs and the definition of the global acceptability of an 'international engineer'. The Canadian efforts, channeled through its International Affairs Committee (now called the Canadian Engineering International Board), the Canadian Engineering Accreditation Board (CEAB) and the Canadian Engineering Qualifications Board (CEQB) are then discussed in terms of the globalization of engineering trades and services and the requirements for efficient bi- or multilateral agreements.

CCPE's current plan for International Affairs is also presented and discussed on the basis of the Canadian experience acquired in many multilateral forums. Of course, this paper does not pretend to bring solutions to all the potential problems of agreements at the international level but it does lay down principles that CCPE is trying to put forward in any discussion.

The internationalization of our profession has brought requirements for very rigorous ways of dealing with multiple eventualities and this paper shares some of the parameters currently used by our committee members who have much experience in the field. It is certainly the beginning, the base for further international discussions on these criteria and philosophies and the authors are looking forward to receiving positive comments and input to ensure that eventual international appraisals are even more productive.

CANADIAN ACCREDITATION PROCEDURE FOR ENGINEERING PROGRAMS

A fundamental requirement for the practice of engineering throughout the world is strong academic preparation. One method that many countries have adopted to ensure adequate preparation is Accreditation of engineering programs. An accreditation system provides an independent mechanism to review and improve programs to ensure that they meet certain standards and reflect current practice.

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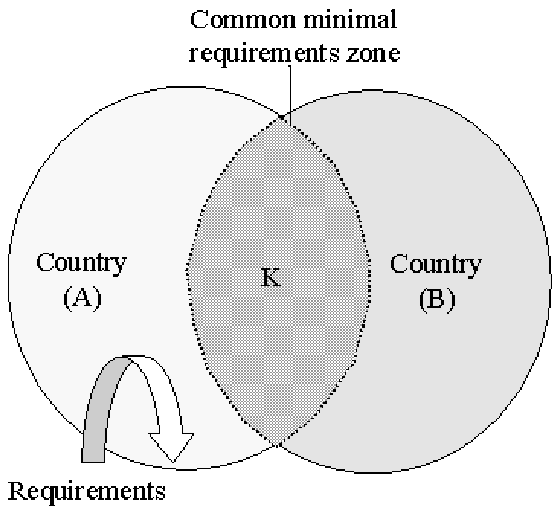

Fig. 1. Overlap of the requirements for two countries.

The detailed requirements of the Canadian accreditation system conducted by the CEAB are covered in a companion paper [1]. The purpose of this section is to position general guidelines, based on the Canadian system, which could be referred to in an international context of equivalency.

It is important to define the notion of 'substantial equivalency'. It does not mean that two accreditation systems or engineering programs are identical. Rather, it means that they are comparable in terms of program content and educational experience and it implies reasonable confidence that the graduates possess the academic competencies to begin professional practice at the entry level.

In general, accreditation criteria refer to both qualitative and quantitative aspects of different requirements [2], generally defined in terms of what might be considered a universal understanding of engineering. This is then augmented by particular requirements that a given country has specified as necessary training for an engineer to satisfy the local practice of engineering. Therefore, certain requirements, either qualitative or quantitative are common to all. From an international point of view, the efforts must focus on the appraisal of the size of this common core and on the size of the different portion [3]. This concept is illustrated in Fig. 1. Two distinct countries must therefore agree upon a minimum overlap area, K. And the amplitude of the requirements in country A must be reasonably similar to those of country B. Consequently, the appraisal of a minimum possible size for zone K is normally a first and important objective in dealing with any country.

The content of K can usually be divided into a basic minimal content upon which everyone will agree. These are the so-called fundamentals of engineering education and these requirements are found almost everywhere. The difficulty in terms of accreditation or substantial equivalency is to quantify these fundamentals in terms of a common measuring stick and to define the size of an acceptable difference, specifically related to other parameters that are found in a particular environment.

Figure 2 represents symbolically how a full program (FP), which can be accredited using rigorous criteria, can nevertheless be significantly different even in Canada. It is certainly not surprising that the same effect can be seen through international comparison. Basically, the minimal size of K plus a minimal content of complementary studies considered acceptable for accreditation strictly determine the basis for any further consid-

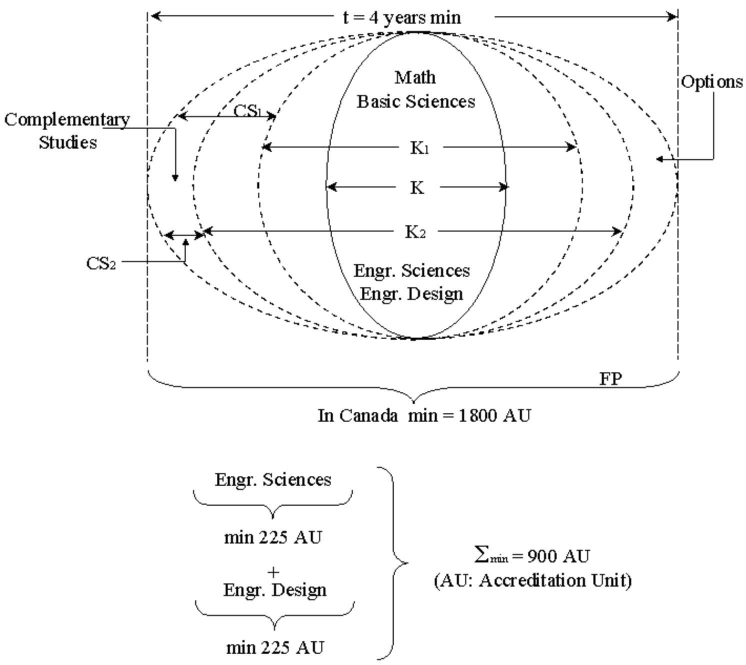

Fig. 2. Minimum core of knowledge for an engineer.

eration for international equivalence of academic qualifications.

Of course an analytical expression for FP (full program) can be expressed by any combination of:

$$\mathrm{FP} = K_i + CS_I \tag{1}$$

where the number of possibilities ($i = 1, \ldots n$) can be quite large. Therefore a basic relationship that satisfies a 'program minimal requirement for international consideration' of substantial equivalency (PMRIC) is:

$$\mathrm{PMRIC} = K_{\min} + CS_{\min} \tag{2}$$

Where systems share a high degree of similarity in their outcomes, objectives and processes, agreements should be straightforward [4]. However, given the variety of systems at the international level, a significant amount of good will is required to correctly evaluate what PMRIC is acceptable.

SUBSTANTIAL EQUIVALENCY

In order to define an acceptable substantial equivalency factor (SEF), other important considerations for granting accreditation must also be taken into account. These factors, such as qualifications and competence of faculty, stability, teaching loads, professional development, dedication, morale, laboratory space and equipment, computer facilities, libraries and others are generally much less quantitative than the program evaluation. Therefore, *monitoring mechanisms* using accreditation units (AU) and a weighting factor must be introduced to consider, with the appropriate flexibility, all the variations that could and must be found to comply with a diversified world with different perceptions.

This weighting factor is heavily based upon a judgment of the adequacy or inadequacy of these additional factors made by peers. Even in a country like Canada, where an accreditation system has been in place for almost 35 years and there is great uniformity among most of the universities, these parameters are evaluated using simple gradings such as acceptable, marginal or unsatisfactory [5]. It is therefore unworthy, at least from the authors' perspective, to try to evaluate this on an international basis using a more accurate system. Therefore, an acceptable SEF has two components: an exact part (PMRIC) as defined in (1), and an empirical part, noted ARIC (Additional Requirements for International Consideration) which has to be weighted by a factor W, with a value between 0 (no consideration) to 1 (full consideration). Analytically, this can be expressed as

$$\mathrm{SEF} = \mathrm{PMRIC} + \mathrm{W}\ (\mathrm{ARIC}) \tag{3}$$

A fundamental question then is: 'What can be reasonably considered by all as an acceptable SEF?' since the level of confidence of any organization or country will be a direct function of the level of that SEF, as defined by their own criteria. This is really the fundamental issue when one tries to enter a substantial equivalency procedure of recognition that could eventually lead to a bi- or multilateral agreement.

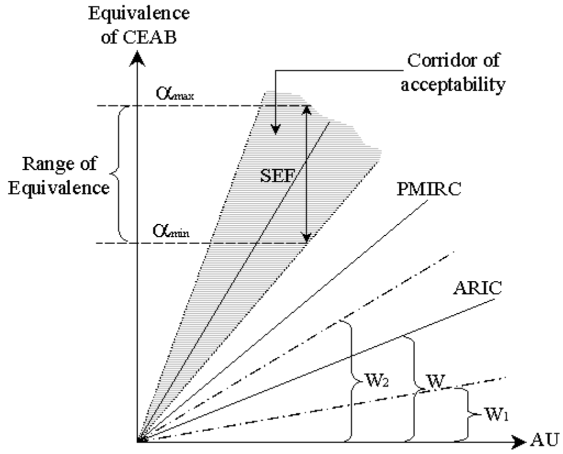

Fig. 3. Weighting of the evaluation parameters

There is an absolute need to put some form of weighting on the meaning of an acceptable SEF in terms of overall confidence. After all, it depends upon many factors including some that could remain unclear even after many investigations. This weighting factor, noted ″ is really the ultimate parameter which would, if correctly appreciated, bring two different organizations to accept one another's approach as equivalent to their own.

If this concept is written under the form of an equation:

$$\text{Equivalence of CEAB accr. Program} = {''}\mathrm{SEF} = {''}(\mathrm{PMRIC} + \mathrm{W.ARIC}) \tag{4}$$

a simple graph can be used to illustrate it (Fig. 3). Of course, equation (4) is never fully respected and, therefore, a total equivalency is not possible, even within very closely related countries. Figure 3 easily shows that the weighting given to the additional requirements determine a corridor of acceptability for the SEF which, in turn, must be appropriately weighted to finally determine the range in which a program can be considered equivalent to a CEAB accredited program.

GLOBAL ACCEPTABILITY

In countries where a registration system for engineers exists, the various elements of the learning pyramid (Fig. 4) normally must be acquired before someone is fully recognized by a professional association, institution or college. It is important to note that the time to complete the education referred to in Fig. 4 is at least 16 years of which at least three years must be at the university level. Failure to meet this level of preparation severely limits the ability to come to an agreement.

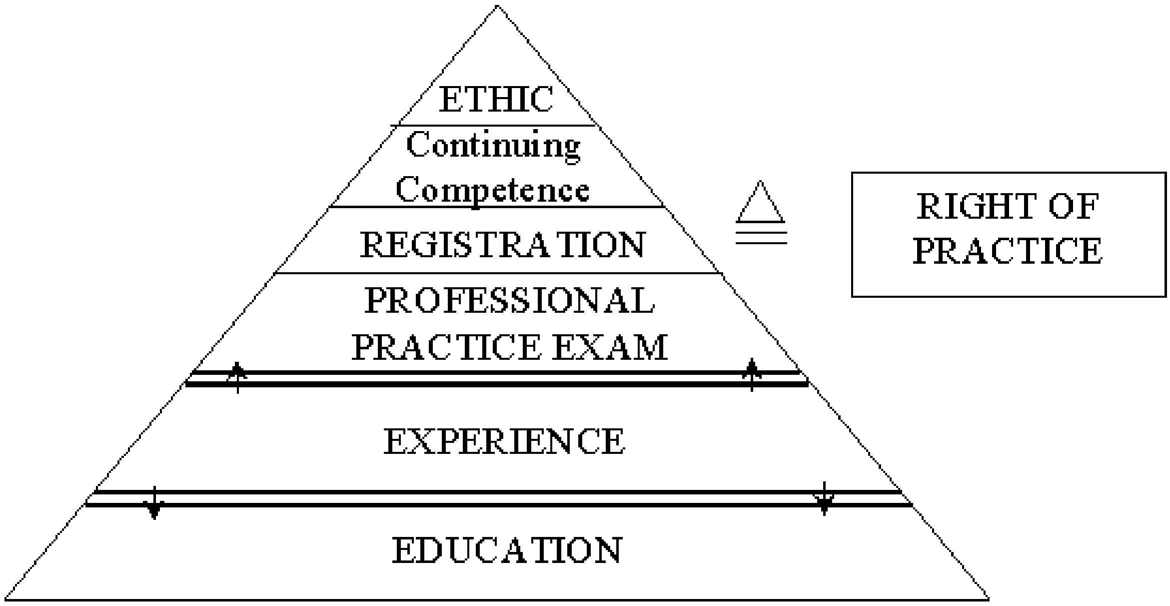

Fig. 4. The learning pyramid.

If the concept of registration exists, full recognition at the professional level should proceed relatively easily.

However, in many countries, including very large and developed countries, e.g. France, the notion of 'right of practice' is non-existent [6]. Therefore, only a subset of the engineering community of those countries can possibly fulfill the requirements elaborated by the pyramid of knowledge. This is particularly true in the experience segment of the pyramid where the requirements fluctuate enormously from one country to the other. It can easily happen that a subset acceptable for one country is not totally acceptable to another.

This is currently the most difficult parameter that must be well understood by everyone in order to eventually come to a global acceptability concept. The minimum requirements for each category have to be agreed upon before multilateral agreements can be ratified. However, on a bilateral basis, it is much easier to come to an agreement on the weighting and values of each of these parameters. This is the strategy of CCPE.

Table 1. Details of Agreements.

Agreements	Countries involved	Academic qual.	Experience	Current status
NAFTA (for engineering)	Canada United States Mexico	—degree from an accredited program (CEAB, ABET, CACEI)	12 years after graduation (8 years after licensure) Continuing competence no requirement	Agreement signed but not fully implemented
ENGINEERS MOBILITY FORUM (FEANI, Japan as observers)	Canada United States Australia New Zealand United Kingdom Ireland South Africa Hong Kong	—Accredited degree (Washington Accord)	8 years after licensure or 4 years in responsible charge of significant engineering work Continuing competence must be maintained	Framework in place to serve as basis for bilateral discussions —Implementation underway
APEC Engineer Project (Hong Kong as observer)	Australia Canada Japan New Zealand Philippines Singapore Thailand China Indonesia Korea Malaysia Vietnam	—Recognized degree (equivalent to Washington Accord)	7 years after graduation at least 2 years in responsible charge of significant engineering work Continuing Competence must be maintained	Framework in place Key participants preparing assessment mechanisms as a guide implemented

GLOBALIZATION OF ENGINEERING TRADES AND SERVICES

In a relatively short period of time much effort has been devoted to defining the concept of an internationally accepted engineer. Of course, to arrive at this ultimate global universality, many bi- and multilateral agreements among various countries will have to be signed.

Amongst the multilateral movements underway to eventually achieve full recognition at the professional level, those that deserve attention at the moment are the NAFTA mutual recognition agreement for engineers, the Engineers' Mobility Forum and the APEC (Asia Pacific Economic Co-operation) Engineer Project.

These three potential multilateral agreements call for different qualifications amongst the participating countries but they all seek to define an MPR (minimum practice requirement). This could serve as a common reference pattern for eventually satisfying all these multilateral agreements and *de facto* defining an internationally acceptable engineer (IAE).

Table 1 provides a summary of these agreements, including the particular requirements and the current status of the negotiations. As one may see by looking at the table, the basic criteria to reach some form of acceptance, call for elements of the pyramid of knowledge for global acceptability, namely the degree and the experience mixed with professional recognition even in their own country.

Apart from the multilateral approach, the bilateral one is certainly at the moment the most frequent form of agreement that involves virtually all major countries and Canada is no exception. The trend toward bilateral agreements is generated by two kinds of needs: first, to serve the best interests of two countries that have common economic and engineering interests and second, to keep the spectrum of conditions for mutual recognition to its simplest form.

A good example of this type of agreement is the one signed between France and Canada (April '98). Basically, it is the first agreement for Canada that grants full recognition at the professional level for Canadian licensed engineers who are graduates of CEAB programs and, reciprocally, gives the same privileges in Canada for French engineers having the title of ingénieur diplomé.

Fundamentally, mutual acceptance by the CCPE and the Commission des Titres d'Ingénieur—France (CTI) of an acceptable SEF was required to strike the agreement. Full verification had determined that both systems, namely the 'Habilitation' process in France and the 'accreditation' process in Canada, were using the same rigorous standards to evaluate engineering programs and that a periodical monitoring mechanism was in place to ensure a continuous or improved level of standards.

A certain number of other forms of organizations for globalization of engineering services have appeared over the last decade and are trying to gain acceptance over an area in which common economic interests lie. This is the case in the European Community where FEANI (Fédération Européenne d'Associations Nationales d'Ingénieurs) is trying to adequately position itself to get eventual international recognition.

FEANI has defined an acceptable SEF among the various (27) countries of Europe that participate in this register of Engineers. This definition [7] is:

$$\mathrm{SEF} = B + 3U + 2(U \text{ and/or } T \text{ and/or } E) + 2E \tag{5}$$

where B represents a high level of secondary education (granted at about age 18), U is a full year of University Education, E represents a year of relevant engineering experience and T represents a full year of training.

Basically, it says that it requires at least 7 years after the baccalaureate to be considered acceptable. Of course, combinations like $5U + 2E$ or $3U + 1T + 3E$ could also be recognized as valid to satisfy the minimum number of years required to be acceptable to the register.

However, difficulties still exist since the ″ factor is not appropriately weighted by all countries. This is mostly because an acceptable monitoring system is not in place or is simply judged deficient. It emphasizes the importance of reaching a sufficient level of acceptance for equations (2) and (3). Otherwise, difficulties will persist since the relationship is established on a confidence basis and relies on the capacity of others to fully monitor themselves adequately.

This example also illustrates the great difficulties associated with a common parameter that has to be applied to a very large set of countries, each having its own rules, academic exigencies, laws and many other factors that influence the global 'exportability' of engineers. These difficulties are not to be neglected and it will take a significant period of time and many other negotiations before a so-called 'Global Engineer' could be defined.

REQUIREMENTS FOR EFFICIENT BILATERAL OR MULTILATERAL AGREEMENTS

The technical requirements of the various engineering programs that exist in the world have been related to the term PMRIC of equation (3). Apart from that, the importance of the other more qualitative requirements, which were related to the ARIC term of equation (3) must absolutely be properly evaluated and weighted to eventually achieve either a bilateral or multilateral agreement.

The most important of these parameters is certainly the confidence in each other's mechanisms to regulate, control, modify and sanction their different constituencies which deal with the

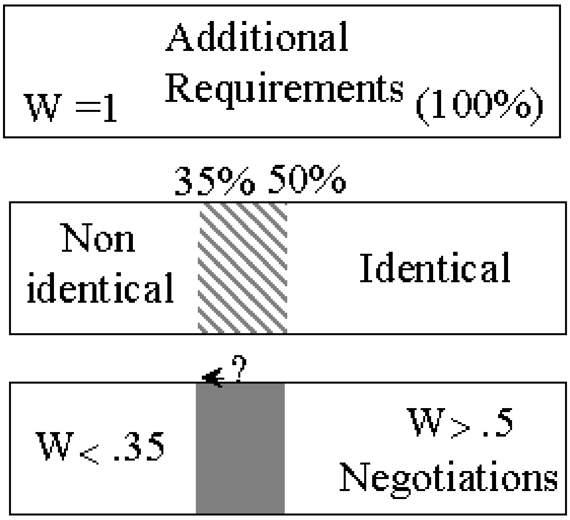

Fig. 5. Appraisal for additional requirements.

delivery of a final product, namely an engineer with a full right of practice. There are two main difficulties associated with this type of confidence:

1. the full appraisal of the rigorous mechanisms that were put together in a country to ensure that their engineering training systems deliver a uniform high quality product;
2. the monitoring mechanisms that must be included in an agreement to satisfy both organizations trying to make a deal together.

The *complexity* of the monitoring system is inversely proportional to the *confidence* that both (or multi) partners have among them. If these control mechanisms are too extensive, the burden of the agreement becomes more important than the possible advantages.

This also raises the fact that some countries have requirements and governance structures that can make it a virtual impossibility to achieve full, country to country, bilateral agreements at the professional level. As an example, the USA has 55 jurisdictions within its territory, each with the legislated authority to govern the practice of engineering. Combine this with their insistence on treating qualified, experienced foreign engineers as entry-level candidates subject to all of the components of the admission process (including examinations) and it makes it virtually impossible to negotiate an agreement with this country even if they do recognize the full equivalency of the PMRIC of equation (3) for many other countries. While they are normally given the privilege to practice in a large number of countries since equation (3) is appraised correctly by other countries, the protectionism of these rules make it almost impossible to envisage an agreement.

It is not the intent of the GATS and other trade agreements to harmonize or reduce regulatory frameworks that are in place. The intent is to make these systems open and transparent and to ensure that any requirements are based on

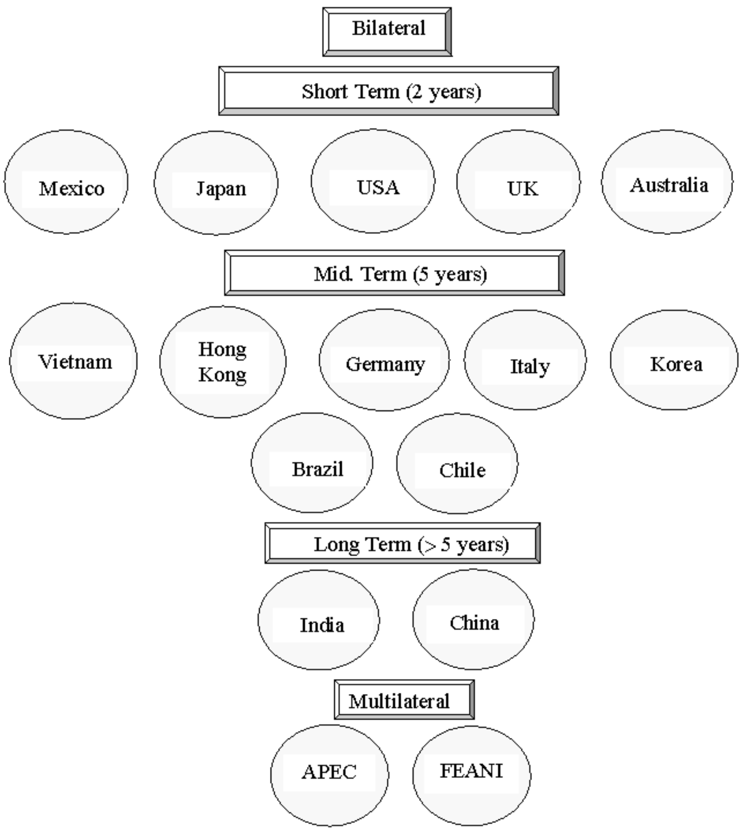

Fig. 6. View of CCCPE International Strategy.

competency, not artificial barriers. The goal of mutual recognition agreements goes further: To really improve mobility by recognizing substantially equivalent outcomes of rigorous formation mechanisms, i.e., professional, competent engineers, thereby eliminating the need for treating experienced engineers as entry-level candidates.

If artificial barriers to full reciprocity agreements do not exist, the other requirements that must be found in a fully deployed agreement can generally be agreed upon. Requirements of the ARIC type do not necessarily have to be identical. In fact, they may be very much different provided that they are of the same nature. A kind of 'intelligent weighting' must, during the course of discussion for an agreement, be made so that these parameters can be found 'acceptable' to the other country.

This is the key to a bi- or multilateral agreement. As an example, Canada, as shown in [1], requires that an accredited program contains material in engineering economics, impact of technology on society, subject matter that deals with central issues, methodologies and thought processes of the humanities and social sciences as well as oral and written communications. But, in no way, does the absence of one or more of these constitute a barrier for a bi- or multilateral agreement.

So far, this has been the Canadian approach to global evaluation of engineering education, i.e. greater flexibility, open-mindedness and respect of diversity.

The weighting to be attached to this ARIC term requires negotiators to have a lot of knowledge of programs in their own country as well as a very reasonable appraisal of what is required in the country (or countries) with which discussions are taking place. A schematic view of this is in Fig. 5. Clearly, our evaluation has shown that below 35% of common ARIC cannot be accepted while 50% and greater will serve as a solid basis for further negotiations.

CURRENT PLANS OF CCPE INTERNATIONAL AFFAIRS

Full recognition of the importance of international affairs has been given by the CCPE Board of Directors. The position of vice-president, International Affairs was created in September 1998 with a specific mandate to supervise, initiate, negotiate and keep track of the international negotiations, agreements, substantial equivalency visits and other activities in which Canada is involved.

Following this nomination, a plan has been made to address the major international issues in a systematic, rational and realistic way. The emphasis is put on two very complementary aspects of international affairs, namely the agreements and the formal assessment of foreign qualifications using CEAB criteria and CEQB guidelines [8].

For the first aspect, the negotiation of international agreements, the plan foresees a major effort to seek agreements with key partners, on a bilateral basis. Figure 6 shows, in a schematic way, the key countries with which Canada will start or be offered to enter into some form of bilateral agreement. The plan is a three-step approach, more or less related to the foreseen difficulties that could eventually be met in seeking these bilateral agreements. The fundamental reason for a bilateral approach is the fact that these key countries will themselves be involved in multilateral agreements along with Canada. And by having a bilateral agreement in process or signed, it is hoped that Canada will be in a strategic position to be a major player in these multilateral negotiations.

Another aspect of the CCPE international affairs plan is devoted to helping other countries to develop or improve their accreditation and licensing systems. Some of these initiatives have been carried out with funding from the Canadian International Development Agency (CIDA) and others are fully on a bilateral basis. This is the case at the moment with Costa Rica where substantial equivalency visits have already been carried out and plans have been made for improvement of the licensing procedure.

Overall, the International Affairs of CCPE are strictly and totally devoted to improvement of relationship between countries toward exchanges or high standard engineering services.

CONCLUSIONS

A general view of the criteria used by CCPE to evaluate engineering education and practice has been presented and some key concepts have been quantified and discussed in terms of global acceptability. Of course, most of these concepts were introduced knowing that it is a kind of original approach to substantial equivalency. More refinements are required in order to receive full acceptance from the various engineering organizations in different countries.

It is hoped, however, that the ideas introduced here will be interpreted as general guidelines for consideration when the academic and professional qualifications of a foreign country have to be rigorously analyzed.

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