

Quality Assurance for Engineering Education in a Changing World*

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Faster computer chips, corporate mergers, new Internet applications: every day, we are reminded of the sweeping technological change and globalization that appear to be dominant trends of the new millennium. Rapid and multifaceted, these changes can be daunting to engineering educators. Unable to predict so volatile a future, we nonetheless have to make decisions today about what to teach future engineers and how to prepare them for an increasingly international workplace without compromising the hard-won quality of our programs. Fortunately, we have an organization dedicated to ensuring the quality and relevancy of engineering education in the US – and, increasingly, to helping engineering education programs in other countries strive for goals similar to our own. The Accreditation Board for Engineering and Technology, or ABET, is a federation of 28 professional engineering and technical societies that accredits some 1,500 engineering programs, 700 engineering technology programs and 50 programs in engineering-related areas. To receive ABET accreditation, engineering programs must go through a rigorous examination that includes self-study and peer review by a visiting team of engineering academicians and professional engineers.

Founded in 1932, ABET significantly boosted the quality and credibility of US engineering programs, but some raised concerns that its rigorous criteria also resulted in too much standardization of engineering programs. In response, ABET has launched a revolutionary make-over of its accreditation procedure aimed at facilitating innovation and creativity. Engineering Criteria 2000, or EC2000, changes the emphasis of the accreditation evaluation from what is taught to what is learned. Administrators will have more leeway in how they set up programs and teachers will have more freedom in what they choose to teach and when, but the results in terms of student achievement will have to be top flight. EC2000 also improves the accreditation procedure in other ways. It requires programs, for example, to show evidence graduates are prepared for the job market. It also requires programs to set in motion a continuous improvement process. Following a three-year period for the procedure to be phased in, ABET will evaluate that all programs under the procedure in 2001. Although it is a major undertaking, ABET's endeavors are far from limited to EC2000. With new technologies such as robotics and so-called 'nano machines' in medicine, traditional engineering disciplines and the applied sciences are becoming increasingly blurred. ABET recently recognized this trend by expanding its mission to include accreditation of applied science programs. Following an agreement with the Computing Sciences Accreditation Board, ABET will have a new commission to accredit computing science programs in 2001.

ABET's most far-reaching work, however, is on the international level. The organization is working closely with engineering societies and educators in many countries to help them develop accreditation procedures similar to the ones ABET uses, such as peer review. This effort has resulted in, among other things, memoranda of understanding with organizations in several countries, including Argentina and France. Other countries with equivalent accreditation procedures, meanwhile, have an agreement known as the Washington Accord that allows for recognition that their basic engineering education meets similar standards. These countries are Australia, Canada, Hong Kong, Ireland, New Zealand, South Africa, the United Kingdom and the US. With engineers working across oceans and continents on a widening scope of projects, the quality and relevancy of engineering education is more important than ever. ABET will continue to strive to keep the bar high.

INTRODUCTION

SINCE 1932, the Accreditation Board for Engineering and Technology (ABET), and its predecessor, the Engineers' Council for Professional Development (EPCD), have been responsible for the assurance of quality in engineering education in the United States. ABET is a federation of 28 professional engineering and technical societies that have joined together to promote and enhance

engineering, technology and applied science education. Over the past decade, ABET has been engaged in a reformation to encourage curricular innovation and to improve the accreditation process while continuing to assure quality in engineering education.

The first step resulted in new criteria for the evaluation of engineering programs, *Engineering Criteria 2000* (EC2000). At the same time, ABET and its stakeholders examined the vision and mission for the organization and for the professional community. As a result, ABET has expanded its mission to include the accreditation

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of applied science programs and negotiated an agreement with the Computing Sciences Accreditation Board (CSAB) to begin accreditation of computing science programs. ABET continues its commitment to the engineering profession and to address the needs of the international engineering community through consultations, evaluations and agreements with educational institutions, professional societies, government agencies and accrediting organizations in other countries in support of engineering educational excellence. This paper summarizes ABET's initiatives in accreditation reform, the move to expand quality assurance to applied science educational programs, and international cooperation.

BACKGROUND

The United States has no ministry of education or other centralized entity managing higher education or promulgating higher education policy. As a result, colleges and universities with diverse missions, objectives, student bodies and methods of educational delivery have developed. This diversity is one of the strengths of the US educational system, but it can lead to unevenness in educational quality. Accreditation is one means of ensuring that minimal educational standards have been met [1]. Accreditation in the United States is non-governmental and is voluntary on the part of the institution or programs being evaluated. The evaluation begins with a self-study by the institution and program. Peer review is an essential element of accreditation. This peer review includes an examination of the institution's and program's self-study and leads to an on-site evaluation. In the case of ABET, the visiting team includes both engineering academicians and practitioners. If the program satisfies the criteria, it is accredited for a period not to exceed 6 years. A report, outlining the strengths and weaknesses of the program as well as any concerns or deficiencies, is provided to the institution.

In operation for over 67 years, ABET currently accredits over 1500 engineering programs, 700 engineering technology programs and 50 programs in engineering-related areas, such as occupational safety, industrial hygiene and surveying [2]. ABET is a federation of 28 professional engineering and technical societies which ensures input from the profession, both industry and academe, in the development of the standards used to evaluate educational programs.

ACCREDITATION REFORM

In the 1930s, engineering programs were evaluated using a simple set of 'guidelines'. Over time, the guidelines became criteria and with the goal of providing clarity became more and more prescriptive. Although the criteria stated that curricular

innovation was encouraged, the reality was that engineering programs were becoming more uniform as a direct result of the pressure to conform to the ABET criteria. In addition, the entire accreditation process was cumbersome and required enormous time commitments on the part of the volunteer evaluators [3]. It was clear that there must be change in engineering accreditation, but that change could not be successfully accomplished without the consensus of the engineering community.

With the input and guidance of industry and education, ABET sought to develop an accreditation system that would provide the means for engineering programs to successfully prepare graduates for engineering practice in the twenty-first century. In 1994, ABET with the support of the National Science Foundation and industry sponsored a series of workshops to examine accreditation criteria, the accreditation process and the participation of technically active, mid-career professionals in that process. The workshops gathered representatives from industry, academe, government and the engineering societies. The fourth workshop synthesized the results of the previous three workshops and recommended a plan of action. The foundation of that plan was the reformation of the criteria used to evaluate engineering programs. ABET could not embark upon either process or participation improvement until the foundation was set.

The consensus of the workshop participants was that the criteria should change the emphasis of the evaluation, with less on what was taught and more on what was learned. It was also clear that industry required graduates to have, in addition to strong technical skills, competency in such areas as communications, teamwork, and an understanding of the non-technical forces that profoundly impact engineering decisions [4]. The Engineering Accreditation Commission (EAC) of ABET took the recommendations of the workshop participants and developed *Engineering Criteria 2000* (EC2000). In 1996, the ABET Board of Directors approved a 3-year phased implementation plan for EC2000. The EC2000 criteria document is now in its fourth edition and includes program criteria for 23 different engineering subdisciplines [5].

EC2000 is essentially unchanged from when it was first envisioned [6]. EC2000 has shifted the emphasis from input measures to student outcomes. The criteria continue to require a strong technical component in the curriculum; however the program has far more latitude in defining how that technical component is structured. In addition, EC2000 requires that the program provide evidence of professional preparation of the graduates. These areas of student achievement range from an 'ability to design a system, component, or process to meet desired needs' to 'understand the impact of engineering solutions in a global and societal context' [7]. It was hoped that this would provide the institutions with the

necessary flexibility to improve their programs. The other crucial component of EC2000 is the requirement for the program to have a continuous improvement process in place for assessing the program's outcomes. The program must set educational objectives using input from the institution's constituencies, assess how well the program is meeting those objectives and provide methods to improve the program as a result of the assessment.

Because this was such a sweeping reform, ABET recognized that it had to gather knowledge and gain the skills to evaluate programs using the new criteria. In addition, ABET needed to identify any major stumbling blocks that the institutions might encounter while attempting to meet the requirements of the new criteria. The ABET Board of Directors approved a pilot study to address these concerns. The EAC, with the support of the National Science Foundation, conducted 5 pilot visits at a variety of institutions in 1996–97. Some of the key findings from the pilot study [8] include the following, for institutions and programs:

- have a sincere involvement of the faculty and a faculty member who is highly committed to developing and guiding implementation;
- fully involve the institution's constituencies in setting goals and objectives of the program;
- have faculty who participate in training sessions and speak with faculty at other institutions;
- coordinate efforts between program assessment and institutional assessment;
- use consultants with caution – there can be positive and negative effects;
- have unique program outcomes;
- do not depend solely on assessment tools with long time constants;
- use several assessment tools, not just surveys;
- lead the evaluator through the evidence, both in the report and on-site.

For ABET:

- training for program evaluators should include both a knowledge and experiential component;
- evaluation must make sense in the context of the discipline and professional practice.

In 1998, ABET began the three-year phase-in implementation of EC2000. During this implementation period, institutions undergoing a general review are able to choose whether to have their programs evaluated using the traditional criteria or EC2000. In 2001, all programs will be evaluated under EC2000. Twelve schools with 54 programs during the 1998–99 cycle chose to be reviewed using the new criteria, while it appears that there will be 47 institutions with 231 programs in the 1999–00 cycle. It was clear from the beginning that such a radical reform in the criteria would require extensive retraining of program evaluators and team chairs, as well as orientation of the faculty and administration of the institutions. ABET, with the support of the engineering societies and the

Engineering Foundation, developed a comprehensive training program for team chairs and program evaluators. With over 550 individuals who have completed the training, it appears that ABET has a sufficient number of trained evaluators to complete the three-year phase-in.

The impact of this accreditation reform extends beyond the Engineering Accreditation Commission. Both the Technology Accreditation Commission and the related Accreditation Commission have new criteria under review that reflect this shift in emphasis to outcomes. In addition, the three commissions are examining ways to jointly streamline their procedures and enhance their training efforts.

APPLIED SCIENCE ACCREDITATION

In 1997, ABET gathered representatives from its many constituencies and explored future directions for the organization. The result was a strategic plan designed to guide the organization for the next few years. Some of the points of discussion of the planning group were the blurring of boundaries between engineering and applied science, the innovations which were taking place at the margins of these disciplines and ways in which ABET could encourage the innovation which would be needed well into the next century. Through accreditation, it might be possible for ABET to draw the engineering and scientific communities closer together while still maintaining the strengths and autonomy of each. ABET had been approached by a number of organizations to discuss the accreditation of their applied science programs. The strategic planning committee responded by recommending that ABET's vision and mission include the accreditation of applied science programs. In 1997, the ABET Board of Directors concurred. In the meantime, discussions had been underway with the Computing Sciences Accreditation Board to integrate their accrediting services with ABET's. In the fall 1998, the two organizations agreed, and in 2001, ABET will have a new commission for the accreditation of computing programs. It is important to note that the concept of peer review will prevail – computer scientists will evaluate computing science programs unless the program has a joint title such as Computer Science and Engineering, in which case there will be both a scientist and an engineer evaluating the program. In addition, members of the computer science community will develop the program criteria used to evaluate computing science programs. However, the accreditation process, itself, which has been made more effective and efficient by ABET will be used. The goal is to lessen the impact on the institution while maintaining the autonomy of the program, to streamline the process for the volunteers, and to assist the computing science and information technology community in assuring quality while

encouraging the innovation necessary to keep the field vibrant and competitive.

What does the future hold for applied science accreditation? As licensure of these professions become the focus of state registration and licensing bodies, accreditation of applied science programs provides a first step in the licensure process. Discussions are under way with representatives from disciplines such as applied geology, and materials science.

INTERNATIONAL COOPERATION

Engineering is a truly global profession, with multinational and transnational corporations employing engineers around the world. In response to the needs of the engineering community, ABET has addressed the issues of quality assurance outside the United States through consultations, program evaluations and mutual recognition agreements [9]. These are not new ventures; ABET has long cooperated with engineering organizations and societies beyond its borders. From 1940 through 1970, the Engineering Institute of Canada was an affiliate member of ECPD (ABET's predecessor). ECPD worked closely with the Canadians to assist them in the development of their own engineering accreditation system. For this reason, there are many similarities in the two systems, but it is important to note that they are not identical. Each system has evolved to meet the unique needs of its constituents. The end result – a graduate who is prepared to begin the practice of engineering at the entry level – is the same.

ABET has also worked closely with the engineering community in Mexico. In 1991, Mexican educational leaders created the Consejo de Acreditacion de la Enseñanza de la Ingeniería, A.C. (CACEI) to develop and implement an accreditation process for engineering programs. To assist CACEI, ABET sponsored a series of workshops for faculty and program evaluators in 1992. Members of ABET's Engineering Accreditation Commission with expertise in the various engineering disciplines participated in the workshops. CACEI has developed criteria for evaluation of programs and has successfully evaluated a number of engineering programs in Mexico.

It is important to note that an integral part of current ABET policy is to emphasize the international engineering educational quality assurance through the development of accreditation systems [10].

ABET has worked closely with engineering societies and groups of engineering educators to assist in the development of effective accreditation systems based on the principles of self-assessment, peer review and stakeholder involvement in the development of criteria. To that end, ABET has met with representatives from numerous countries, sponsored a series of international workshops on

accreditation system development, provided materials and speakers for symposia outside the United States, and encouraged observers on site visits, at training programs and to decision-making meetings. To formalize this process, ABET has entered memoranda of understanding (MOU's) with organizations in several countries. In 1991, ABET signed a letter of intent to provide consultation to the Ukrainian Ministry of Higher Education and to assist in the development of an accreditation process in the Ukraine [11]. Elsewhere in Europe, ABET has met with representatives from Russia and Germany. After an exchange of observers and a review of processes in 1997–98, ABET signed an MOU with the Commission des Titres D'Ingenieur (CIT) in France [12]. ABET has also worked closely with various entities in Latin America. In 1995, ABET signed a MOU with the Regional Office for Science and Technology for Latin America and the Caribbean of the United Nations Educational, Scientific and Cultural Organization (UNESCO) [13]. The two organizations agreed to cooperate in the organization and implementation of national and regional engineering evaluation and accreditation activities. ABET representatives have led seminars on accreditation in El Salvador and Honduras in 1996–97 and participated in conferences in Brazil, Costa Rica and Argentina in 1997–98. As a result of discussions during some of these conferences and seminars, ABET signed a MOU with the Comision Nacional de Evaluacion y Acreditacion Universitaria (CONEAU) [14] of Argentina in 1997.

MUTUAL RECOGNITION AGREEMENTS

As noted above, ABET (then ECPD) closely followed the development of an engineering accreditation system in Canada. It became clear that cooperation was beneficial to both accrediting organizations. In 1979, ECPD signed a mutual recognition agreement (MRA) with the Canadian Engineering Accreditation Board (CEAB) of the Canadian Council of Professional Engineers. This agreement went beyond an exchange of information, but extended recognition to the comparability of the two systems. Reaffirmed twice, the longevity of this mutual recognition agreement (MRA) demonstrates its success. The agreement states that 'each party adjudges the accreditation decisions rendered by the other party to be acceptable and substantially equivalent evidence of acceptable educational preparation of graduates for the practice of engineering at a professional level' [15]. Both ABET and CEAB have worked to keep this agreement strong and healthy. Each year, the two organizations exchange visitors to observe campus accreditation visits as well as observe the meetings of the accreditation decision-making bodies. In addition, ABET and CEAB exchange copies of their current criteria and lists of accredited

programs which they, in turn, publish or make available to their respective licensing/registration entities. This review and exchange of information on processes and procedures has led to the identification of 'best practices' and has strengthened both accreditation systems.

Over the years, a number of countries with mature accreditation systems viewed the success of the ABET/CEAB MRA. Countries with an educational tradition similar to that in the United States and Canada expressed a desire to develop a similar agreement with ABET and CEAB. In 1989, representatives from engineering education accrediting organizations in Australia, Canada, Ireland, New Zealand, the United Kingdom and the United States signed an agreement originally known as the Six Nation Accord. Subsequently other accrediting organizations sought signatory status and the Six Nation Accord became the Washington Accord. The Engineering Council of South Africa (ECSA) became a signatory to the Accord in 1993 and the Hong Kong Institute of Engineers (HKIE) in 1995. Full acceptance into the Accord requires ratification by all the signatories. Ratification of ECSA is incomplete pending verification of its accreditation processes and procedures by CEAB (Canada) and ABET. Verification of HKIE's processes and procedures are complete, and HKIE's admission has been ratified.

The Washington Accord recognizes the substantial equivalency of accreditation systems to assess that the graduates of accredited programs are prepared to practice engineering at the professional level. The Accord provides a mechanism for the mutual recognition of first professional degrees or basic engineering education among the countries. Each of the accrediting or professional bodies participating in the Washington Accord remains independent and autonomous. Each country is responsible for its own accreditation standards and evaluation procedures. Lists of accredited programs are provided to all signatories. Signatories are encouraged to recommend to their respective licensing bodies that the graduates of a program accredited by one of the signatories be accorded the same privileges as the graduates from accredited programs in the home country. However, licensing and registration bodies are not bound by this agreement.

In 1997, the biennial meeting of the Washington Accord Signatories was held in Washington, DC. The signatories met to clarify admission procedures and other provisions in the original agreement. The signatories wanted an agreement that was simple and straightforward and that had accompanying rules of procedure. A new Washington Accord was drafted and signed. It retained many of the provisions of the original agreement, but also included provisions for the admission of new members to the Accord, provided for monitoring and verification activities, and limited recognition to accredited programs in the home

country. The signatories elected a chairperson and secretariat for the agreement. The United States was elected chair and Australia was elected to serve as the secretariat. Accrediting organizations in Mexico, France, Russia and New Guinea are seeking signatory status.

ENGINEERING MOBILITY

One of the other topics of discussion at the 1997 meeting of the Accord signatories was whether to extend the agreement to address international mobility of practicing engineers. A subcommittee of the Washington Accord, the Hong Kong Working Party, studied the issue and recommended that the Accord limit itself to the substantial equivalency of accreditation systems. The signatories endorsed the concept of the creation of a new, separate organization to examine mobility issues. As a result, representatives from the Accord countries established the Engineers Mobility Forum. This group is examining the international mobility of engineers and the recognition of professional qualifications. The United States is represented in the Forum by the United States Council for International Engineering Practice (USCIEP). USCIEP is a federation of three US organizations: one representing engineering practice, one representing licensure/examination, and ABET representing education. USCIEP was organized originally to negotiate enabling procedures to support the provisions of the North American Free Trade Agreement (NAFTA) regarding professional services. Prior to that time, there was no single, unified professional body in the US that could speak on all aspects of engineering from education to licensure and practice. USCIEP has since gone on to participate in discussions within the Asia Pacific Economic Cooperative (APEC).

CONSULTING AND SUBSTANTIAL EQUIVALENCY EVALUATIONS

Since the 1980's, ABET has sent teams of expert consultants to advise engineering programs as to their strengths and weakness and to make recommendations for improvement. ABET visited programs in Kuwait, Egypt, the USSR and the Netherlands. The evaluations closely paralleled the evaluation procedures and criteria used by the Engineering Accreditation Commission. In 1991, ABET formalized the procedures and policies used to evaluate programs at institutions outside the United States. These programs are not 'accredited', instead they are deemed to be 'substantially equivalent' to those accredited in the United States. 'Substantial equivalency means comparable in program content and educational experience, but such programs may not be absolutely identical in format or method of delivery. It implies reasonable confidence that the graduates possess the

competencies needed to begin professional practice at the entry level [16].’ Programs are recognized as ‘substantially equivalent’ for a period not to exceed 6 years. ABET has evaluated and recognized over 70 programs at 14 institutions in 10 countries [17].

Up to this point in time, ‘substantial equivalency’ evaluations have been conducted only for engineering programs and only using the conventional engineering criteria. Recently, the International Activities Committee of ABET has received requests to evaluate engineering technology programs and to evaluate engineering programs using *Engineering Criteria 2000*. The committee is considering these requests and may evaluate programs on a pilot basis in the near future. It is clear that any effort to extend EC2000 evaluations beyond US borders will require an educational process comparable to the one in the United States. The ABET International Activities Committee is examining ways in which this can be accomplished.

EDUCATIONAL CREDENTIALS EVALUATION

Assessment of the educational credentials of engineers is a concern of employers, attorneys, graduate schools, and licensing/registration bodies. To address this need, in the fall of 1997 ABET established a service to evaluate the educational credentials of engineers who attended institutions outside the United States. Engineering

Credentials Evaluation International (ECEI) evaluates credentials using the ABET engineering criteria in effect at the time the applicant graduated. Mutual recognition agreements, such as the Washington Accord, and substantial equivalency recognition form the basis for evaluating educational credentials. Evaluations that are based on academic documentation alone are limited in scope and do not address such issues as computer, laboratory and design experience or communication skills. Over 300 evaluations were completed in 1998.

FUTURE DIRECTIONS

Engineering education will need broad shoulders to carry the responsibilities being assigned to it today. Some things we brought into the 1990’s are now seriously challenged, and some are changing [18].’

ABET continues to keep its mission and vision in focus. Quality assurance in engineering education, regardless of the arena, will continue to be of primary importance to ABET. The means, the methodology, even the underlying philosophy may change, but the overall objectives will remain the same. For this reason, accreditation and cooperation are key. ABET will continue to partner with organizations around the world to ensure that engineers receive the education they deserve and that the profession and the public can rely on that level of educational quality.

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