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ABET's EC2000 Criteria – The Model for Outcomes-Based Accreditation Criteria

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2001-2002 ABET President

In writing this article for the *The Interface,* I am reminded of a "one-liner" that goes like this, change is good – you go first. ABET's engineering criteria, the so-called EC2000, place more emphasis on what students learn than what they are taught. This is the major change that has occurred in engineering accreditation, the, so-called, outcomes-based accreditation criteria. Many other professional and regional accreditation agencies, in the United States and worldwide, are now considering adoption of outcomes-based accreditation criteria. However, ABET "went first" and its EC2000 criteria are now the model for other accreditation systems.

Although we now have several years of experience with the EC2000 criteria, some programs will receive their first evaluation under EC2000 criteria in 2004 or 2005 and we have not yet completed a full accreditation cycle. However, already there is evidence of positive response to the new system from several sources. As mentioned above, many other regional and professional accreditation systems are in the process of adopting outcome-based criteria. The Chemical Engineers have undertaken a major review of their curriculum requirements, the first in many years. Programs have discovered weaknesses, duplication, and gaps in the topics covered and have corrected them. Faculty teaching different portions of the curriculum are better communicating with each other and have better focused the objectives of their courses.

However, some have accused the EC2000 criteria of dummying engineering programs. Some are saying that ABET has diluted or weakened the requirements for accreditation and that it is impossible for a program to fail an EAC evaluation under these criteria. It is difficult to understand these criticisms when even a cursory reading of the full EC2000 criteria reveals that much of the previous criteria are retained and that an objective of EC2000 is to insure that graduates of an accredited basic engineering program are prepared to enter engineering practice

In addition to retaining criteria for Students, the Professional Component, Faculty, Facilities, Institutional Support and Financial Resources and Program Criteria, the EC2000 criteria contain two new criteria titled "Program Education Objectives" and "Program Outcomes and Assessment". Most of the differences between the engineering topics criteria (i.e. the "old" criteria) and the EC2000 criteria are found in these two criteria.

Although these two criteria have received the most attention, they are also the most misunderstood. Some have concentrated on these, ignoring the requirements of the other general criteria and the program criteria. Taken in their entirety and in proper context, the EC2000 criteria are rigorous yet non-prescriptive. In addition to the requirements for rigorous technical engineering skills, graduates of a program accredited under EC2000 criteria must have communication skills, the ability to work on multi-disciplinary teams, understand professional and ethical responsibility, recognize the need for life-long learning, and understand the impact of engineering solutions in a global and societal context. These graduates compare favorably to graduates of programs accredited under the "old" engineering topics criteria. To quantify this comparison, ABET has initiated a longitudinal study to compare quantitatively the abilities and successes of the EC2000 criteria. Although this study will likely be a

[i] The opinions expressed in this article are those of the author

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long-term continuing effort, progress reports will be issued, as results are available.

Background for Change

Many younger engineers and engineering faculty members do not remember the "old" ABET criteria. These criteria had evolved into many pages of small font type. They were prescriptive, somewhat restrictive, and sometimes contradictory. Although the "old" criteria specifically stated that ABET encouraged innovation, the reality was that programs tended to be conservative and resistive to change. The word on the street was that ABET was a "bean counter".

In response to criticisms and suggestions from its constituents, the Engineering Accreditation Commission (EAC) of ABET decided to develop new criteria and that the new criteria were to be more revolutionary than evolutionary. In other words the EAC would essentially adopt a clean slate and write new criteria for the accreditation of engineering programs. Following this momentous decision, ABET, with the support of the National Science Foundation, conducted a series of workshops designed to involve its stakeholders in setting the guidelines for these new criteria. The result of these workshops was that while the new criteria were to be significantly different, the best of the "old" criteria would be retained and the new criteria would focus on what students learn as opposed to what they were taught.

The EC2000 Criteria

The new criteria were adopted by ABET in 1996 and a phase-in period began in 1997. The new criteria soon became known as EC2000 or Engineering Criteria 2000 because it would be the 21st century and the new millennium before they were fully implemented.

The EC2000 criteria consist of

I. General Criteria for Basic Level Programs (including program criteria), and
II. General Criteria for Advanced Level Programs

The General Criteria for the basic level programs contain criteria for

1.Students
2.Program Educational Objectives
3.Program Outcomes and Assessment
4.Professional Component
5.Faculty
6.Facilities
7.Institutional Support and Financial Resources
8. Program Criteria.

The criteria for Students, *Professional Component*, Faculty, Facilities, and Institutional Support and Financial Resources are similar in language and intent to the previous engineering topics criteria. The program criteria provide the specificity needed for interpretation of the basic level criteria as applicable to a given discipline. Each program must satisfy the appropriate program criteria as well as the general criteria.

The EAC considered carefully the language of criterion 4, the *Professional Component* and, in the end, retained much of the language of a similar criterion found in the engineering topics criteria. The professional component requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The criterion states specifically that the students *must be prepared for engineering practice*. The criterion also states that the professional component of an engineering program must include:

(a) one year of a combination of *college level* mathematics and basic sciences (some with experimental experience) *appropriate to the discipline.* (Note: the italics are the author's.)
(b) one and one-half year of engineering topics, consisting of engineering sciences and engineering design *appropriate to the student's field of study*
(c) a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives

This general criterion applies to all engineering programs seeking accreditation. Guidance as to what mathematics, basic sciences and engineering topics are appropriate to the discipline and the student's field of study is found in the program criteria. The general education component replaces the previous requirement for humanities and social sciences. The wording of this portion of the criterion is intended to ensure that this important component receives adequate planning and attention.

Criterion 5, *Faculty*, requires that a program have a sufficient number of faculty members, with appropriate competencies and qualifications. It also requires that this faculty have sufficient authority to ensure the success of the program. Additional requirements for faculty are found in the program criteria.

Criterion 6, *Facilities*, while similar to a related criterion in the engineering topics criteria, specifically promotes professional development and professional activities. It requires that students must have the opportunity to learn the use of modern engineering tools with adequate computing and information infrastructures in place.

Program Criteria, Criterion 8, have an important role in the EC2000 criteria. They provide the specificity needed for interpretation of the basic level criteria as applicable to a given discipline. They provide guidance to programs and their constituents as to the meaning of terms, such as "appropriate to the discipline", found in the basic level criteria. The program criteria are written in terms of outcomes and do not specify specific courses. As an example of the specificity found in program criteria consider the program criteria for *Civil and Similarly Named Engineering Programs*. These criteria are "Curriculum" and "Faculty".

Curriculum

The program must demonstrate that graduates have:

- proficiency in mathematics through differential equations; probability and statistics; calculus-based physics; and general chemistry;
- proficiency in a minimum of four (4) recognized major civil engineering areas;
- the ability to conduct laboratory experiments and to critically analyze and interpret data in more than one of the recognized major civil engineering areas;
- the ability to perform civil engineering design by means of design experiences integrated throughout the professional component of the curriculum;
- An understanding of professional practice issues such as: procurement of work; bidding versus quality based selection processes; how the design professionals and the construction professions interact to construct a project; the importance of professional licensure and continuing education; and /or other professional practice issues.

Faculty

- The program must demonstrate that faculty teaching courses that are primarily design in content are qualified to teach the subject matter by virtue of professional licensure, or by education and design experience.
- The program must demonstrate that it is not critically dependent on one individual."

The criterion for *Program Educational Objectives* requires that a program seeking accreditation must have detailed educational objectives and that these objectives must be consistent with the mission of the institution ***and the EC2000 criteria***. The criterion also requires that the program have a system of ongoing evaluation that demonstrates achievement of the program objectives and uses the results to improve the program.

The criterion for *Program Outcomes and Assessment* requires that a program demonstrate that its graduates (i.e., students) have certain abilities and understandings. There are 11 specific (i.e., a-k) items listed in the criterion that are believed to be necessary characteristics of a modern engineer. The list contains many of the suggestions that educators and ABET have received from industry employers over a period of many years. Many of these items also apply to other professions if taken in the context of those professions. The criterion also requires that the program measure the abilities and understandings of its graduates, assess the measurements, and apply them to further improve the program. The requirement to demonstrate that a graduate has a specific ability is much more stringent than a requirement that the graduate has completed a specific course.

The requirements that a program have educational objectives, a system of ongoing evaluation, program outcomes with an assessment process, and demonstration that progress and improvement in the program is continuing initially created much concern among the institutions and their engineering programs. Words such as educational objectives, program outcomes, assessment, and evaluation were not universally understood. However, there is evidence that these requirements are beginning to be understood by the program faculty and others and that acceptance is rapidly growing. **Gloria Rogers** has written an excellent practical guide to assessment in the spring 2003 *ABET Communications link*, the ABET quarterly news source.

Criteria Development

Before a criterion becomes an ABET criterion it undergoes a lengthy development and adoption process. ABET's general and program criteria are developed first by its commissions who recommend them to the ABET Board of Directors for adoption. The commissions are made up of representatives of the 33 professional societies that compose ABET. For example, the EAC is responsible for recommending criteria for all engineering programs. This is the largest of ABET's four commissions and the collection of professional societies represented in the EAC is perhaps the most inclusive representative body of engineering in the United States. (The ASEE might take exception to this statement, however the ASEE is a member of the EAC.) Typically program criteria are suggested to a commission by the appropriate professional society. For example, the IEEE would be expected to develop and recommend to the EAC program criteria for Electrical, Electronic and Similarly named programs. The EAC studies and debates the proposed program criteria and makes recommendations to the full EAC. The EAC also makes suggestions for general criteria and changes to its general criteria.

The ABET Board of Directors then adopts the proposed new criteria for a period of review and comment by all interested parties including the general public. This review period is typically 2-3 years. The proposed new criteria are published in the same document as the current criteria for all to examine both the existing and proposed criteria. Only after surviving the review and comment period are the criteria adopted by the ABET Board of Directors and then becomes ABET criteria. This procedure allows all interested parties to make their views and opinions known and considered.

Summary

Today, outcomes based accreditation criteria is being widely considered for adoption by professional and regional accreditation agencies in the United States and worldwide. This is occurring concurrently with rapid technological development, with the introduction of many new specialty areas, and the blurring of traditional boundaries between engineering disciplines. The format of ABET's EC2000 criteria, i.e. outcomes-based, is highly suited for adaptation to these new technologies and new disciplines. ABET can be justly proud of its role as leader in this effort.

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Time for individual-centered learning

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We are struggling through an education revolution that started over a decade ago with the first flutter of the technology revolution. The National Science Foundation, American Society for Engineering Education, US Department of Education, and other industry/university consortia have studied and agonized over what would or should happen. A decade later, colleges and universities are plunging in or in some cases backing in (either because of economics or fear) to a new educational delivery system.

In the next decade more conferences, committees and symposia will sort out the new pedagogy and best practices. They will consider what the next round of technological innovations will mean for engineering education.

Distance learning, however, isn't waiting for the perfect set of circumstances. Currently there are millions of students graduating from universities that have all brushed up against individual-centered learning in one way or another. They've done that despite problems with bandwidth, compression techniques, viruses, or energy outages.

As reported in the *Washington Post*, 4 September 2003, The Campus Computing Project 2002 study of more than 640 public and private universities nationwide estimates 80 percent of higher education classes employ e-mail and the Internet for some form of student instruction. Furthermore EDUCAUSE, a nonprofit that provides computer training and support for 1,900 colleges, universities, and educational organizations, reports that instructors at most universities are under tremendous pressure from administrators and students to distribute course material over the Web and through e-mail.

The 1998 reauthorization of the higher education act sought to help universities advance into the 21st century by aiding with grant money for models of cooperative distance learning. US state universities from California to Massachusetts already have respected, self sustaining, distance learning programs for undergraduates, graduates and professionals. Private universities have been slower to construct programs, but they too are beginning to do it. Add to this the 3.5 million students at various institutions worldwide who receive instruction through the *blackboard.com* platform. Then add in the 33 universities in the US that are strictly online learning centers.

Either little by little or in some cases in one fell swoop, the way students are taught is changing. Going from group-centered to individual-centered learning strategies puts the habit of control and responsibility of learning in the hands of the student and her incarnation as a professional learner for the rest of her life. Current students have had to work online in a variety of guises, whether for an entire course, team project, or finding learning objects for subjects they need extra help on at a digital library.

To realize the most from individual-centered learning, the student must be disciplined, self-reliant, and motivated. Again, circumstances aren't waiting for a new sort of student to come along. Universities and colleges are teaching motivation in the old "sink or swim" mode by raising tuition and cutting course availability. Some universities are doing away with entire majors to bridge the gap in their budgets. In response to US state budget cuts this year, according to "The Rising Price of Higher Education" report by William Trombley for the National Center for Public Policy in Higher Education (2003), in all but two states both 4-year and 2-year colleges increased their tuition and cut their course selections.

When these students begin their careers they already have the habit of working online and the expectation of educational self-reliance. Industry has been crying for workers who could be flexible. And now universities are turning out those who can engage in "just-in-time" skill building. But Industry will have to assure professionals access to cutting edge seminars, tutorials, and courses. Industry will have to make room in their tight schedules for time to devote to updating skills and learning new knowledge.

In return, Industry can expect to save on dedicated classroom space, teachers, time and travel costs. But they need help in identifying and delivering classes to their employees. That is where the IEEE Educational Activities Board (EAB) has taken the lead.

According to the Christopher Burns study of industry needs, done for the IEEE EAB in 2001, "there is a high degree of interest in finding a better way to keep their engineers' technical knowledge up to date, and a great deal of enthusiasm about a potential role for IEEE."

This year, in response to the study, EAB has added a new initiative to offer an online individual-centered educational opportunity. The new EAB initiative addresses industry based delivery using the IEEE Xplore platform. The EAB will partner with Societies, which have the content practicing professionals seek. Industry can partake by subscribing.

Four prototype courses captured in an interactive online format from the timely, cutting edge tutorials and short courses offered at Society conferences will be available for evaluation by selected industry human resources managers by December 2003. If their response is favorable, then all 40 IEEE Technical Societies/Councils will be invited to partner with the EAB in the delivery of online educational modules based on their conference tutorials and short courses. The modules will be mounted on the IEEE Xplore platform (which is just now considering the delivery of wide-band, multimedia content) and distributed through the IEEE Electronic Library (IEL). They will also include appropriate test sections which must be passed should an individual wish to obtain IEEE Continuing Education Units (ICEUs) for the learned material.

While the IEEE educational modules are being worked on, members can exercise their online skills by accessing the following individual-centered learning opportunities:

The Learning Communities, http://www.ieee.org/organizations/eab/vc/index.htm, provide a forum to network with colleagues who have a shared common purpose. The virtual community recognizes that not everyone can get to a conference and addresses those that do need a venue to continue discussions outside the conference setting. Communities are arranged by subject matter, so that you can get acquainted with other fields of study.

The Education Partners Program, http://www.ieee.org/organizations/eab/eduPartners.htm, provides discounts on selected courses at 17 universities and corporate providers. Technical as well as management courses are available any time, anywhere.

The IEEE EAB continues to take measured steps to provide a variety of new online educational options for both Industry and the IEEE membership. As more and more of our members go into the workforce with the expectation of directing their own continuing education, the IEEE EAB will be there to support them.

Engineering Education Reform: A Path Forward

The Trilogy — PART III

Abstract

A compelling case for engineering education reform has been made over the past 16 years. Although there has been progress, resistance to change continues unabated, notwithstanding the numerous calls for action, increasing competition from alternate service providers, as well as "student-pipeline" and job-security problems. The engineering education reform movement has been clouded by mixed, and sometimes conflicting, messages. This paper identifies this and other core problems impeding progress. The National Academy of Engineering (NAE) is seen as taking a more active part in engineering education reform – taking action to help identify and resolve some of the vexing problems faced by engineering education reform, and, most important, leading by example.

I. Background and Introduction

A myriad of articles, papers, books, workshop and conference proceedings, and more have made a compelling case for engineering education reform. Among these are the 1994 ASEE Green Report [1], the 1995 National Research Council's Board on Engineering Education (NRC BEEd) Report [2], and recent calls for change by the NAE leadership, President, William F. Wulf and Chairman, George M. C. Fisher [3, 4]. Working together, then NAE Chairman Norman Augustine and MIT President Charles Vest, led the effort behind the formulation of the authoritative ASEE and NRC reports. In fact, Vest chaired the NRC's Report Review Committee while Augustine wrote the Foreword for the NRC BEEd Report, wherein, he agreed with the report's conclusion: "*that, in many areas, major change in the engineering education system is indeed necessary if it is to meet the needs of the nation and the world in the coming century*." [2, p vii].

Although there has been progress, resistance to change continues unabated, notwithstanding the numerous calls for action, increasing competition from alternate service providers, as well as "student-pipeline" and job-security problems that have been brought to national attention. There appears to be no clear path forward and an apparent absence of focused, action-oriented leadership. Additionally, recent times have seen the engineering education reform movement clouded by mixed, and sometimes conflicting, messages, for example:

- An assessment effort was outlined in the preface of the 1994 ASEE Green Report as follows: "*Over the next few years, the ASEE Engineering Deans Council will lead the effort to assess what engineering colleges are doing to affect change, refine the action items of the report, and set milestones for assessing future progress toward their implementation*" [1, p 1]. The follow-up assessment effort was never implemented.
- The epilogue of the NRC BEEd Report opens with: "*The BEEd is well aware that major changes in large, decentralized systems, such as the engineering education system, are seldom realized as a direct consequence of a single stimulus such as this report. Rather, such changes usually reflect a gradual shifting of opinions, attitudes, and practices arising from a recognition and clearer understanding of new external conditions and concomitant new internal needs and emphase*s." [2, p 55]. True enough, but, to some, in contrast to the tone set in the Foreword and main body of the report, the words could be interpreted as a disclaimer or "escape clause" – providing a pass on implementing change, saying, in effect, that there need be no sense of urgency about engineering education reform. The statement could also be interpreted as a hedge – cautioning against unrealistic expectations, such as the timely adoption of the needed changes in engineering education spelled out in the main body of the report.
- One purpose of the 1998 Engineering Foundation Conference – *Realizing the New Paradigm for Engineering Education,* was to highlight a new program, *Action Agenda for Systemic Engineering Education Reform* that stemmed from recommendations made at a July 1995 workshop convened by the Engineering Directorate of the National Science Foundation [5]. This new program was to be administered through the NSF Engineering Directorate, and was to encourage proposals to this program from the engineering education community. Following the conference, changes at the NSF Engineering Directorate led to changes in programmatic emphasis, and the Action Agenda Program was discontinued after the first two rounds of awards.
- "*Thus if engineering education does not change significantly, and soon, things will only get worse over time. The problem has now been studied to death, and the solution is clear. So let's get on with it. It's urgent that we do so*," said Wulf and Fisher in the latest published word on the emphasis to be placed on engineering education reform [3].
- The philosopher Alfred North Whitehead remarked, "*The task of the university is the creation of the future, so far as*

rational thought, and civilized modes of appreciation, can affect the issue." In a recent article, Stanley Katz used this remark to initiate his questioning the role of the modern university. "*But for many of today's academics, rationality is in question, civilization is anathema, and universities have not created, for themselves or for their societies, the future Whitehead envisaged. What, then, are we about? If, as Stanley O. Ikenberry, former president of the American Council of Education, has claimed, American universities are "at the top of their game," then just what game are they playing, and what's the prize*? [6]"

Although it was most encouraging to see the Wulf-Fisher statement, and Wulf's strong reiteration of this message at the 2002 ASEE Annual Conference [4], the previous events and statements sent disquieting messages of equivocation to those who have worked, and are still working, in the engineering education reform movement, and who might have expected much more rapid progress after the publication and widespread promulgation of the ASEE and NRC reports than was seen up through 1995. It is troubling not to see the development of a shared sense of purpose within the engineering education community since the publication of the 1986 NRC Report on Engineering Undergraduate Education [7]. It is also troubling to see that this sense of purpose must be developed within university communities that are in need of transformation themselves [8] – university communities that are very likely not "at the top of their game" as seen by Katz.

Change continues to proceed at geologic speed despite the ardent efforts of Augustine, Vest and many others during the mid-1990s. Why might this be so and what might be done to accelerate the pace of change? These are obvious questions, the answers to which are complex and institution dependent, not amenable to a one-size-fits-all resolution. Nonetheless, after a brief discussion of interrelated problems, a path forward is proposed in the following. The NAE is seen as playing a major role – taking a more active part in engineering education reform than heretofore – unequivocally demonstrating that: "*it is strongly committed to moving engineering education's center of gravity to a position relevant to the needs of 21st-century society*" [3]. This means moving beyond the present set of Academy programs in this area [3, 4] to a new level – taking action to help identify and resolve some of the vexing problems impeding progress in engineering education reform, and, most important, leading by example.

II. Engineering Education Reform: Some Core Problems

According to the Boyer Commission: " *universities too often continue to behave with complacency, indifference, or forgetfulness toward that constituency whose support is vital to the academic enterprise*" [9, p 37]. A survey conducted three years after publication of the Boyer Commission Report indicated that research universities have made considerable headway in recent years [10]. However, the survey "*also suggests that most efforts have been directed at the best students; the challenge for almost all is to reach a broader spectrum of students*."

It is believed that there is much more behind the reticence of some of our engineering schools to adopt change than complacency, indifference, forgetfulness, and even the routine resistance to change that characterizes organizations and institutions that consider themselves "successful" in doing what they are currently doing. In fact, there are powerful interrelated counter-reform forces at work, or, put another way, interdependent forces that work to maintain the status quo. Engineering education reform is at least partially dependent on the resolution of some of the interrelated problems; of these, the following are considered core problems:

A. Academic Resistance to Change

In the academic variant of the "innovator's dilemma" [11, p 448], many of our research-intensive universities, faced with enormous financial pressure, struggle to maintain and grow the (largely) government-fueled, resource-intensive infrastructure created to pursue their research missions [6, 8]. Apparently, it is their view that they cannot afford to invest human and physical resources in undergraduate engineering education reform where they perceive little, if any, near-term gain in the way of financial rewards or other payoffs that will help support their primary research mission.

Additionally, a generation or more of faculty members have been hired and promoted at many of our research-intensive institutions primarily because of their strengths in research and "grantsmanship." Relative to undergraduate teaching, many of these faculty members consider research to be inherently more personally fulfilling, more valuable to the profession and society, and more rewarding in terms of awards, prestige, and honors – including potential for election to the NAE. Additionally, the continued presence of faculty unions may hamper efforts to change faculty incentive systems [2, p. 32].

The deans, faculty, and administrations who oppose change could be unwittingly undermining the long-term viability of their engineering schools in the engineering education marketplace. It is not surprising, that opposition to change can come from some of the contributors to the NRC study – not surprising, since most people ultimately act in what they see as their near-term, vested self-interest.

B. Academic Resistance to ABET Oversight and Accountability

The NRC BEEd Report contains the following recommended action: "*The Engineering Dean's Council or other appropriate group should continue working cooperatively with the Accreditation Board for Engineering and Technology in its reassessment of accreditation criteria in accordance with the types of changes suggested in this report and implemented in response to current and future needs in engineering education*" [2, p 53]. The types of changes suggested in the NRC BEEd Report, are not likely to take place in most engineering school curricula without a forcing function such as the ABET criteria. Unfortunately, the very mention of ABET to engineering administrators and faculty often brings out powerful negative emotions and the perception of an imposed solution – an automatic trigger for opposition. ABET also brings to the table problems related to perceptions of remnant "bean counting" and an almost insatiable appetite for data. Based on their past experience and deep-seated, bad, memories of ABET's old bean-counting ways, it should come as no surprise that a good number of the schools tend to look past the merits and opportunities related to change.

They will likely view any potential change in ABET EC 2000 as a precedent-setting threat to their academic autonomy and a first step on the "slippery slope" to the return of ABET bean-counting "with different colored beans."

To find an example that illustrates contrary behavior and the strong opposition that can be mounted against the types of changes suggested in the NRC BEEd Report, one need look no further then a January 2002 request for endorsements of a proposed one-word change to ABET EC 2000 – adding the word environmental to Criterion 3f [11, p 448]. Academic opposition to the proposed change seemed based on ABET involvement in the process, rather than on the substance of the proposal.

Further to the point, consider an "ideal-world" process wherein engineering schools, after a self assessment of their missions, decided to incorporate changes recommended in the NRC BEEd Report that are appropriate to their stated missions. In other words, each school exercised its freedom to devise a revitalization program that fits the context of their institution, their student body, faculty, and objectives. To assure that the schools are doing what they said they would do, suppose that the expected outcomes of their programs are gauged by the ABET EC 2000 process relative to the school's goals. Experience teaches that, under present, real-world circumstances, it is not likely that this ideal process will ever be implemented. It is only "natural" that the faculty will resist additional workloads for which there is little, if anything, in the way of rewards or recognition. Aside from "doing the right thing" for their undergraduate engineering students, they have little incentive to do otherwise.

The apparent opposition-to-reform strategy is to treat ABET in an adversarial manner, providing as little support as possible – reflecting the short-term, operational advantage attendant to a "weak" oversight function and the low value placed on activities that are not related to the school's research mission. The adversarial relationship between some of our leading engineering schools and ABET is considered one of the more vexing problems impeding progress in engineering education reform.

C. Academic Resistance to Electing Qualified Engineering Educators to the NAE

When considering resistance to change at various levels of the academic enterprise, the real issue is not whether research is favored over teaching, but how best to tie research to teaching in the most productive way, or, to redefine research to include teaching [12, p 23]. However, the recent history of engineering education reform suggests that the rules of the "zero-sum" game dominate the mentality of those opposed to change and governs the dynamic tension that characterizes all aspects of the engineering-research vs. engineering-education-practitioner struggle – from NSF program budgets to the "pecking order" at our engineering schools, and, for that matter at the NAE.

The predominance of engineer-researcher NAE members, appears to provide strong positive feedback, via engineering-school rankings by *US News and World Report* (*USNWR*), promotion and tenure decisions, and various other "reward and recognition" mechanisms, that works to maintain the status quo in engineering education at our research-intensive engineering schools as well as at the many schools that are using these research-intensive schools as models for "success." Put another way, NAE focus on the election of its members on the basis of individual engineering-research contributions provides an indirect, but tight, constraint on the changes urged by a number of individuals, study committees and boards, including those in the ASEE and NRC reports [1, 2] and those espoused by current NAE leaders [3, 4].

The dearth of prestigious, national-level, rewards and recognition for high-quality contributions to engineering education – particularly, election to membership in the NAE – is considered to be one the root causes for the slow and halting progress of systemic engineering education reform. The problem stems from the relatively low value placed on undergraduate engineering education by many engineer-researchers, and the institutions that profit from their contributions. It is likely that some academic institutions will not want to "waste" effort and political capital, as well as risk missing a possible increase in *USNWR* rankings, on candidates from a present-day "who cares" area with relatively low-payoff in terms of prestige and peer recognition.

Additionally, there are a number of special people in engineering education – they form a veritable "who's who" of individuals who have distinguished themselves by high-quality contributions in this area. The fact that educators of such high-caliber are not members of the NAE stands as a salient challenge to the credibility of the NAE re: the value the Academy, as a whole, places on high-quality contributions to engineering education. Most likely, such eminently distinguished engineering educators will not be considered "worthy" of NAE membership by the majority of electing NAE members so long as: 1) Noteworthy contributions to the field of engineering education are thought of as merely supplemental to the primary qualifications of: important contributions to engineering theory, practice, and literature, and/or demonstration of unusual accomplishments in the pioneering of new and developing fields of technology; and 2) Engineering education is not considered as a principal branch of engineering activity with an assigned NAE engineering category/section and associated peer-review committee.

It is understood that education is already in the NAE nomination and membership criteria, just as it is in all the Academic Faculty Codes. So, simply putting in writing that it is a valid reason to nominate and elect will likely do as much good within the NAE as it does with faculty merit criteria at engineering-school promotion and tenure committee meetings. That is why the second item is essential so as to help assure that engineering education receives significant attention from some of the best minds in the engineering community. Perhaps a few of these should, and would, make the dominant part of their contribution to engineering education. Also, there is something of value about significant contributions to the engineering literature, where appropriate. Perhaps it is not well known in the academic-scientific-research community that the ASEE *Journal of Engineering Education* and the IEEE *Transactions on Engineering Education* are peer reviewed and archived publications.

So long as the NAE continues to elect its members the way it does, it will perpetuate the status quo, or, as Roderick G. W. Chu put it: "*If you keep doing what you have always done, you're going to get what you always got*" [13]. Ernest Boyer also said it well: "the time has come to move beyond the tired old "teaching versus research debate" and give the familiar and honorable term "scholarship" a broader, more capricious meaning, one that brings legitimacy to the full scope of academic work" [12, p 16].

All things considered, what seems to be required is some “out-of-the-box” thinking and doing.

D. Lack of Forceful Industry Input

Without strong input from industry, the academic engineering community is not likely to institute changes in their engineering programs, a point well made by Karl Martersteck, a retired industry executive and member of the NAE: “*Industry must establish the “requirements” for the quality and education of the engineers they hire. Unless, and until, major industrial leaders whose views are generally respected speak out and say that they will not hire engineers unless the engineers have the broader ”new paradigm” education, academics will continue to pursue their present course”* [14]. Unfortunately, the long-term views of industrial leaders often are not communicated to company representatives on ABET committees and engineering school advisory boards, as well as to project managers and campus recruiters who write and execute requisitions – knowing their company is being evaluated in the marketplace by its share price and they on near-term results. Industry leaders can also work to have engineers treated as professionals rather than as “commodities” [15].

III. An Outline for a Path Forward

It would appear that the task before us is to enlighten the various stakeholders in engineering education. Specifically, we need to show that the (remarkably consistent) changes recommended by Wulf and Fisher, the ASEE and NRC reports [1-4], as well as other related reports and papers, are not only feasible, but that it is in the current and future self interest of our engineering schools to embrace the changes appropriate to the context of their institution, its student body, faculty, and objectives. The NAE can play a major role in this enlightenment by placing its imprimatur on the changes recommended in the ASEE Green and NRC BEEd reports and by providing unequivocal and visible demonstrations *“that the Academy attaches great value to creative work in engineering education and wishes to acknowledge and spread the best ideas*” [3]. Some suggested avenues of approach are as follows:

A. Academic Institution and Faculty Path

A primary objective of the 1998 Engineering Foundation Conference was to examine what were then thought to be some of the best undergraduate engineering programs [16]. This examination provided an outline for the development of several structural models that incorporated the requisites for implementing and maintaining “good” programs. A complementary set of models was added by Splitt [14]. The next step involves making it attractive for schools to commit themselves to change from what they do now to something approaching an appropriate one of the models. In view of increasing competition and advanced technology delivery systems, Splitt [14] argues that it is in the long-term-economic self interest of our engineering schools to cope with the upcoming shift in the engineering education marketplace by implementing programs that reflect change, such as those outlined in the NRC BEEd Report. This may very well be one of those problems where anecdotal and inferential evidence is all that we will have; where once the shift arrives in force, it will be too late for the schools to deal with it – the market will have already decided. Nevertheless, it is suggested that the NAE can play an important role via a substantive study of the economic threat to the future of our research-intensive engineering schools.

Achieving and maintaining the needed changes in academic culture is a long-term effort. It requires the identification, support, and nurturing of change agents in engineering schools across the country. A related issue appears to be maintaining sustained administrative support for change. Engineering deans cannot realistically mandate a culture change, but they can set a tone and use their limited discretionary funds to help assure that change is not stifled when it appears. Again, we need to assure that engineering education receives significant attention from some of the best minds in the engineering community. Those that make innovative undergraduate engineering education the dominant part of their contribution will do much to improve student retention and encourage graduate study, to the ultimate benefit of the academic research community. It is suggested that the subject of engineering-school enlightenment in these, and other areas such as student enrollment and retention, and practitioner job security, be considered as study topics for NAE working committees – including, with the study deliverables, a related list of actions that could be taken to catalyze change and continuous improvement.

B. ABET Related Path

Resistance to ABET oversight and accountability notwithstanding, the outcomes based structure of ABET EC 2000, coupled with its call for greater documented involvement of engineering education “constituencies,” appears to provide the key for change and for keeping the change fresh on a program-by-program basis. A strong, credible, and respected ABET organization can play an essential role in the realization of systemic engineering education reform. The NAE can facilitate the development of these attributes by not only working with ABET, but also by encouraging engineering schools to do so as well. Furthermore, NAE leaders can encourage the ASEE Engineering Dean’s Council, engineering professional societies, and other appropriate groups to follow the 1995 NRC/BEEd Report recommendation to work cooperatively with ABET in its reassessment of accreditation criteria in accordance with the types of changes suggested in the report and implemented in response to current and future needs in engineering education. The NAE can also work to: 1) Determine better ways (than ABET-related) to stress (to engineering students) that environmental and other “non-technical” factors covered in the NRC BEEd Report are very important to consider up front in engineering design and that engineers have an important social responsibility; and 2) Study ways and mechanisms aimed at the resolution of ABET-related issues and problems.

In the likely ongoing process of evaluating the relative priorities of NAE engineering education initiatives, consideration might be given to leveraging the NAE’s connection with the ASEE Engineering Deans Council to encourage the Deans to express their ABET-related concerns and to offer ABET-free alternative solutions to introducing the changes recommended in the NRC BEEd Report at their engineering schools. If it is the view of an engineering school that utilizing ABET Criteria is not the best way to introduce these changes, they could be asked to provide their thoughts and suggestions as to better ways – and, to the specific ways their school would be willing to commit to an implementation schedule.

C. A Path for Electing Qualified Engineering Educators to the NAE

With reference to the discussion of academic resistance to electing qualified engineering educators to the NAE, NAE President

Wulf has advised, via personal communications, that the new criteria have been adopted as stated in the following excerpt from the Wulf-Fisher paper [3]: "*First, we've reaffirmed that high-quality contributions to engineering education are a valid reason for election to the NAE. This criterion makes it clear that people's creativity and excellence in engineering education can be rewarded in the same ways as outstanding technological contributions*." This is an encouraging first step. However, as implied in the previous section, simply putting in writing that it is a valid reason to nominate and elect candidates for the NAE is a necessary, but not sufficient, condition to assure a sustainable election process for worthy candidates in engineering education.

Boyer's definition of scholarly activity [12, p 16] and the NRC BEEd Report's expanded working definition of scholarship [2, p 46], provide further rationale for recognizing engineering education as a principal branch of NAE engineering activity, and alignment of the NAE with this recognition as a priority activity. It would seem that this would be a straightforward approach to the resolution of the credibility problem, as well as the taking of a big step in addressing the larger problem of academic rewards and recognition. This move to inclusiveness would focus the attention of the academic community on the high value the NAE places on engineering education. It is the linchpin of an overall strategy aimed at breaking down the extant barriers to more rapid progress in engineering education reform and assuring the technical health of our nation.

IV. Prognosis

The suggested action items outlined above can be summarized as follows: 1) Recognize engineering education as a principal branch of engineering activity and align the NAE with this recognition as a priority activity; 2) Encourage the development of a strong, credible, and respected ABET organization; and, 3) Conduct substantive studies aimed at problem identification/resolution and engineering-school enlightenment as to the long-term benefits, to the school and its ultimate customers, of implementing changes appropriate to the context of their institution, its student body, faculty, and objectives. So what might we expect in the way of outcomes?

Many billions of dollars have funded the mission shift of many of our engineering schools from teaching and service to research. Consequently, it is expected that consideration of the suggested NAE initiatives, particularly, the inclusion of engineering education as a principal branch of engineering activity, would be an emotionally wrenching issue and give rise to a tough debate. The debate should reveal how deeply the value placed on educational contributions by the NAE leadership has penetrated the majority of current NAE members, some of whom are part of the group of faculty members that have been hired and promoted primarily on the basis of their research strengths. These academic-engineering researchers will likely opt for exclusiveness and oppose a move toward inclusiveness. It will require a profound change in attitudes, demanding much more than statements by NAE leaders, to overcome what may very well be a deeply embedded culture of engineering-researcher elitism.

When speaking of the difficulty in responding to change at our colleges and universities, James Duderstadt provided insights that, to some degree, are applicable to change at the NAE: "*It may be necessary to drive an organization toward instability, toward chaos, in order to shift it from one paradigm to the next. Sometimes this happens naturally as external forces drive an organization into crisis, sometimes it results from the actions of a few revolutionaries, and sometimes it even happens through leadership, although as Machiavelli observed, it is rarely well received by those within the organization* [8, p 268].

To put the issue in perspective, one need consider lost-opportunity costs. Most likely, the suggested initiatives would have a ripple effect beyond measure – enabling the breakdown of extant barriers to engineering education reform. With so much to be gained in benefits and apparently nothing of real consequence to be lost, follow up on the suggested initiative would be well worth a serious and intensive effort. Absent a dedicated effort, it is very likely that the status quo will prevail, leaving engineering education reform to founder. However, there is reason for optimism. With appropriate education, management, care and the good will of those who have the means to influence the process, in due course opponents of change, defenders of the status quo, will be enlightened and proceed to act in their enlightened self interest. The NAE culture will change so that it will be possible for the NAE to become proactive in engineering education reform and for exemplary contributors to engineering education to be elected to the Academy on a sustainable basis. In turn, this will catalyze change in academe and accelerate the pace of systemic engineering education reform.

V. Conclusion

The formidable challenge to change in our engineering education system demands no less than a formidable and coordinated response as well as able and respected leadership. The NAE has the wherewithal and is well positioned to provide this response, as well as to provide requisite leadership by example. It would be a credit to the NAE, and a boon to engineering education reform/revitalization, if the NAE would work to implement the suggested initiatives. These initiatives could very well provide the breakthrough that, over time, would enable the widespread implementation of the changes needed in the engineering education system – helping to motivate and mobilize the stakeholders in engineering education to address the challenge to change. The stakeholders – academic administrators and faculty members, students, government policy makers and agency program managers, and professional society as well as industry leaders – should see this as clarion call to action on their parts as well. As stated in the epilogue of the NRC BEEd Report: "*The education of this nation's engineers deserves no less*" [2, p 55].

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Author's Biography

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From the President of ECEDHA

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It is a pleasure for me as incoming president of ECEDHA to take over the job of writing this column from **David Soldan** (2002-2003 president), and to continue his lead in sharing some of the activities and issues ECEDHA is presently engaged in. Over the past year, ECEDHA has increasingly pursued a more proactive role for the organization in addressing national issues such as nanotechnology education, diversity in ECE programs, and the future of ECE education itself. In this column, as well as future ones, I will report on some of these varied activities.

As reported by Dave Soldan and other board members in the April issue this year, ECEDHA partnered with the National Science Foundation and the International Engineering Consortium (IEC) to organize a two day workshop on *NanoEngineering Education* held January 27th and 28th, 2003, in Santa Clara, CA. The two-day workshop was held in connection with the IEC DesignCon 2003 Conference. Over 50 representatives from ECE departments across the country participated in the workshop. A full day of tutorials which broadly defined nanotechnology was provided by international experts in the field, and available online on the IEC website www.iec.org/nanoevent. The second day of the workshop was solely an academic workshop for ECEDHA members and representatives, with the purpose of addressing the educational challenges of nanotechnology, particularly as it impacts Electrical and Computer Engineering programs. A full report on the workshop has now been completed, and submitted to NSF, and will be available on the ECEDHA web page as well as through NSF for dissemination. Some of the action items arising from this workshop include establishment of a NanoEducation committee in ECEDHA to, for example, document best practices in nanotechnology education and faculty development. A proposal is made in the report to establish a Nanotechnology Web Education Center (NWEC) in collaboration with IEC that will provide a national repository for nanoengineering education educational materials such as course modules, visualization tools, simulation software, etc. Also, a proposal is made for ECEDHA and NSF to partner in organizing summer workshops in collaboration with established university nanotechnology research centers for faculty and teachers to gain more experience in this field, and help develop curriculum and course materials relevant to nanoengineering education.

The NSF Electrical and Communication Systems Engineering Directorate in collaboration with ECEDHA, held the *Agents of Change Workshop* June 17th and 18th, 2003, at the NSF in Arlington, Virginia. The purpose of the workshop was to bring together the chairs, deans and faculty members representing ECE programs in the U.S. to share best practices and discuss innovative strategies to significantly enhance the diversity of the student and faculty bodies. The vision of diversity discussed in the workshop includes the development of a welcoming and nurturing climate in educational institutions for women and underrepresented minority groups in ECE. As "Agents of Change," the workshop participants were invited to help formulate a national agenda and action plans for recruitment and retention of faculty members, graduate, undergraduate, and K-12 students. At the workshop, this goal was achieved through keynote speeches by the NSF leadership, who discussed the importance and goals of diversity; presentations from deans and other leaders from academic institutions and organizations that have demonstrated results in developing diverse talents; and breakout sessions that involved extensive discussions. A summary report is presently being drafted for publication in Fall of 2003, which I intend to discuss in more detail in a future column.

Last year, ECEDHA collaborated with the *IEEE Education Society* to solicit contributions for a special issue of IEEE Transactions on Education devoted to providing a vision of the undergraduate curriculum for ECE in the year 2013 and beyond. Contributions were invited from electrical and computer engineering departments, as well as industry, government and other interested professionals, on their vision of what ECE departments should be offering in the year 2013 and beyond in order to adequately prepare students for their future as practicing engineers and graduate students. Both regular full length manuscripts addressing specific curriculum, as well as short papers framing the discussion of the future of ECE education were received and peer reviewed. The special issue is presently scheduled for publication in November, 2003. The articles accepted for publication range from addressing broad curriculum issues to future pedagogical models, including the influence of technology enhanced education. Overall, a variety of interesting and provocative visions of future engineering education are presented in this issue, which we hope will provide a framework for the future evolution of ECE education.

One of the most visible ongoing ECEDHA activities is the annual meeting. The 2004 meeting will be held March 19th to the 23rd, 2004, in Orlando, Florida. In this year's meeting -ECE: Leading Technology Awareness- we will again follow on themes developed at last years meeting in Oahu related to ECEDHA's more proactive stance. The program will have sessions on many areas of interest to the membership, including:

- Key Technology Issues
- Liberal Education for ECE Students
- Engineering Curricula for High Schools
- EC2000 Experiences and Evolution
- Bio-education for ECE Students
- Public Policy and ECEDHA
- Small School Issues
- The Role of ECE in Emerging Technologies
- Engineering Education Research
- Diversity

In addition to panel sessions and plenary talks, the annual meeting will as usual provide an open forum for members, a business meeting including the results of the ECEDHA annual survey, regional meetings, and of course a large amount of time for simply catching ups with old friends and making new acquaintances. This year's meeting will also include, as in the past, the New Chairs workshop and the EC2000 workshop for programs slated for accreditation visits in 2005. An IEEE ABET Visitor Training Workshop will also be held in conjunction with the annual meeting on Sunday, March 21st. Details of this years meeting may be found on the ECEDHA website, www.ecedha.org/2003-04/agenda.html.

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From the Chair of the ASEE ECE Division

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The *2003 ASEE Annual Conference* in Nashville included another successful program offered by the ECE Division. I was pleasantly surprised by the good attendance at the business meeting (Monday 7:00 a.m.!) and many attendees volunteering to help with our 2004 program and activities. As 02/03 division chair I was also honored to be invited to attend IEEE EAB meeting Saturday June 21 also held in Nashville (Opryland Hotel.) During my presentation I encouraged continuing the close relationship between IEEE, ASEE (especially ECE Division) and various government organizations and industry. Due to encouragement from our university administration (President Bailey, Provost Litynski, and Dean Atkins) I feel privileged to be able to continue my involvement with professional/technical organizations including IEEE, ASEE, ECEDHA, NSF. I think it is essential for both teaching and research faculty to get involved in these professional societies and industry/business and government organizations should encourage their staff members to support ASEE, IEEE and related activities. As a glance at 2003 Annual Conference will show, our sessions were well organized and included topics in accreditation, research directions, ECE lecture/laboratory courses & innovations, discussion items (BSEE or now BSECE session), teaching and learning with technology, mathematical concepts in ECE subjects, and various administrative and society meetings.

On the IEEE side of things, we had the third IEEE eit (electro/information technology) Conference in Indianapolis, June 8-11, 2003. Professor Lotfi Zadeh gave the banquet keynote speech on soft computing and computation with alphabets and impressions and recent developments in intelligent systems. Luncheon speaker was Dr. Vasundara Varadan, Division Director of NSF's Electrical and Communications Systems. These eit conferences were started in Chicago in June 2000, we are planning to have the conference at Milwaukee in June 2004 (hosted by MSOE.)

I want to conclude my remarks by mentioning two very important awards which were presented at the Nashville Conference (see the pictures in the article): The ECE Distinguished Educator Award was presented to Dr. **Pamela Leigh Mack**, Professor and Chair, Morgan State University. The ECE Meritorious Service Award recipient was Dr. **Daniel M. Litynski**, Provost and V.P. for Academic Affairs, Western Michigan University. Congratulations! to both Pamela and Dan for doing an outstanding job and for their valuable contributions to our technical/professional societies.

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Mousavinezhad presenting Distinguished Educator Award to Dr. P. Leigh Mack.

Mousavinezhad presenting Meritorious Service Award to Dr. Daniel M. Litynski.

Technical Sessions with papers presenting latest teaching innovations in engineering/technology education, laboratories and research. Exhibits, Workshops, Awards Banquet. Topics of interest include:

Latest discoveries related to all engineering and technology disciplines, Accreditation (ABET) Issues, Laboratories, Distance Education, Teaching & Learning With Technology, New Directions in Research, Capstone Courses, Innovations in Undergraduate/Graduate Education, NSF or other Funded Research with Education Emphasis, Capstone Experience, Technical Communications, Cooperative Education, Relations With Industry, Advising and Retention Issues, Gender Issues, Nanotechnology, Interdisciplinary Programs, Software Tools, Curriculum Development.

Both hard copies and electronic forms of **ABSTRACTS** (maximum one page, in PDF) should be sent by **December 15, 2003** to Hossein Mousavinezhad, ECE Department, Western Michigan University, Kalamazoo, Michigan 49008, (269) 387-4057, FAX (269) 387-4096, ***h.mousavinezhad@wmich.edu***, ***http://www.wmich.edu/ece***
Camera Ready Full Papers will be due in March 2004 (please refer to conference Web Site for up-to-date information about the conference, registration, etc.)