The ABET "Professional Skills" – Can They Be Taught? Can They Be Assessed?

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ABSTRACT

In developing its new engineering accreditation criteria, ABET reaffirmed a set of "hard" engineering skills while introducing a second, equally important, set of six "professional" skills. These latter skills include communication, teamwork, and understanding ethics and professionalism, which we label process skills, and engineering within a global and societal context, lifelong learning, and a knowledge of contemporary issues, which we designate as awareness skills. We review these skills with an emphasis on how they can be taught, or more correctly learned, citing a number of examples of successful and/or promising implementations. We then examine the difficult issue of assessing these skills. We are very positive about a number of creative ways that these skills are being learned, particularly at institutions that are turning to global and/or service learning in combination with engineering design projects to teach and reinforce outcome combinations. We are also encouraged by work directed at assessing these skills, but recognize that there is considerable research that remains to be done.

Keywords: professional skills, ABET, assessment

I. INTRODUCTION

On November 2, 1996, the ABET board of directors approved what initially became known as Engineering Criteria 2000 (but is now simply the ABET engineering criteria). In approving these forward-looking criteria, the board allowed for a two-year pilot study and a three-year phased implementation period, making the criteria effective for all engineering programs beginning in 2001. Not only did the board change the criteria, it also changed ABET's operating philosophy. According to Prados, one of the leaders of this effort, this was the more significant development. To Prados and others, ABET accreditation had become rigid and rule-bound over its sixty years of existence, resulting in almost thirty pages of fine print that detailed requirements for course credits and distributions, faculty staffing, and laboratory facilities [1]. Now, three pages of 12-point, easy-to-read type replaces the fine print. Included in the new criteria is Criterion 3—a set of eleven outcomes that all engineering baccalaureate graduates should possess. These can be divided into two categories—a set of five "hard" skills and a second set that we call "professional" skills. Not surprisingly, the hard skills include [2] (with changes adopted on October 28, 2004 in italics):

- an ability to apply knowledge of mathematics, science, and engineering (3.a);
- an ability to design and conduct experiments, as well as to analyze and interpret data (3.b);
- an ability to design a system, component, or process to meet desired needs *within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability* (3.c);
- an ability to identify, formulate, and solve engineering problems (3.e); and
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (3.k).

It is this second set of six outcomes, the professional skills, that have created the most controversy and that are the subject of this paper:

- an ability to function on multi-disciplinary teams (3.d);
- an understanding of professional and ethical responsibility (3.f);
- an ability to communicate effectively (3.g);
- the broad education necessary to understand the impact of engineering solutions in a global, *economic, environmental,* and societal context (3.h);
- a recognition of the need for, and an ability to engage in lifelong learning (3.i); and
- a knowledge of contemporary issues (3.j).

Although certain engineering educators refer to these as "soft" skills, often in a naïve and occasionally derogatory fashion, they have been referred to as professional skills for at least the past decade. Smerdon notes that the American Society for Engineering Education's (ASEE) 1994 *Engineering Education for a Changing World* calls these professional skills [3]. That landmark document and the new ABET engineering criteria are among the most important initiatives to impact engineering education in the past fifteen years.

In this paper we describe the evolution of the professional skills in engineering education, explain why they have become a critical concern, and discuss how they can be taught and assessed. In doing this we have delineated the professional skills into two types: process oriented and awareness oriented. This orientation motivates how they can be best taught and assessed. For a more complete specification of all eleven outcomes, we refer the reader to an earlier, comprehensive study with our colleagues Cynthia Atman, Ronald Miller, Barbara Olds, Gloria Rogers, and Harvey Wolfe [4].

II. EVOLUTION OF THE PROFESSIONAL SKILLS

To briefly summarize how we reached this point, consider the following. As described by Ernst [5], since the founding of the ASEE in 1893, practically every decade has witnessed a major study of engineering education that collectively has shifted the focus from course content to the development of students as emerging professionals. Yet, even at that initial ASEE meeting, William H. Burr, professor of civil engineering at the Columbia College School of Mines stated, "The first and fundamental requisite in the ideal education of young engineers, a broad, liberal education in philosophy and the arts, is a precedent to the purely professional training" [6].

Perhaps the most significant of these studies was the 1955 Grinter Report [7]. Issued after a three-year study, that report transformed engineering education from its pre-World War II format to one that was solidly rooted in the basic sciences and engineering science. Specifically, it called for:

1. strengthening work in basic sciences (math, physics and chemistry);
2. identifying and including six engineering sciences that draw upon the basic sciences;
3. integrating the study of engineering analysis, design, and engineering systems to provide professional background in a manner to stimulate creative and imaginative thinking, while making full use of the basic and engineering sciences;
4. including electives to develop the special talents of individual students, to serve the varied needs of society, and to provide flexibility of opportunity for gifted students;
5. a continuing, concentrated effort to strengthen and integrate work in the humanities and social sciences into engineering programs;
6. an insistence upon the development of a high level of performance in the oral, written, and graphical communication of ideas;
7. encouraging experimentation in all areas of engineering education;
8. strengthening graduate programs in order to supply the needs of the profession; and
9. taking steps to ensure the maintenance of faculties with the intellectual capacity as well as the professional and scholarly attainments necessary to implement these recommendations.

Yet, as forward thinking as these recommendations were at the time, the report's opening sentence indicates how far we have come in the past fifty years:

> "Engineering education must contribute to the development of men who can face new and difficult engineering situations with imagination and competence."

Certainly, these distinguished educators did not envision that women might enter the profession in substantial (but still not sufficient) numbers.

More recently, the last two decades have marked a period in which a series of reports from government, industry, and academia has called into question the state of engineering education and paved the way for including the professional skills as learning outcomes. In 1985, the National Research Council's *Engineering Education and Practice in the United States: Foundations of our Techno-Economic Future* called on universities to make faculty careers more attractive in order to fill vacancies [8]. This was followed by the NSF-supported Belmont Conference [9]. Smerdon credits this conference with leading to the creation of the National Science Foundation's (NSF) undergraduate engineering education coalitions initiative [10], probably the one NSF program that has had the greatest impact on engineering education to date.

Starting in the early 1990s, a series of reports emerged that recognized serious deficiencies in engineering education and called for major reforms. The ASEE's *Engineering Education for A Changing World* proclaimed that "engineering education programs must not only teach the fundamentals of engineering theory, experimentation, and practice, but be relevant, attractive, and connected," preparing students for a broad range of careers and lifelong learning. It stated that engineering education must provide the "technical knowledge and capabilities, flexibility, and an understanding of the societal context of engineering" [11]. The NSF's complementary report, *Restructuring Engineering Education: A Focus on Change,* stressed similar themes [12]. Among its recommendations is that engineering education should become flexible enough to support diverse career aspirations and engineering courses that would include a broad range of concerns: environmental, political and social issues; international and historical contexts; and legal and ethical ramifications.

The National Research Council's Board of Engineering Education also recommended a number of actions for curriculum reform "including early exposure to 'real' engineering and more extensive exposure to interdisciplinary, hands-on, industrial practice aspects, team work, systems thinking, and creative design" [13]. Three leading educators, Bordogna, Fromm, and Ernst, called for educators to "create an intellectual environment where students can develop an awareness of the impact of emerging technologies, an appreciation of engineering as an integral process of societal change, and an acceptance of responsibility for civilization's progress" [14].

At the 1992 Engineering Foundation Conference on "Engineering Education: Curriculum Innovation and Integration," Pister proposed reformulating the goals of engineering education as developing technical competence, understanding the practice of engineering as a social enterprise, acquiring clinical experience in practice, preparing for management and leadership roles in society, and building a foundation for lifelong learning. To Pister, examining the trade-offs among these objectives and selecting the appropriate weighting in a particular curriculum would present one of the more difficult challenges for faculty [15].

As noted, the Belmont Conference's call to revitalize engineering education led the NSF to create its Engineering Education Coalitions program, a bold initiative aimed at "revolutionizing" education [16]. In all, eight coalitions involving more than sixty schools were funded. Collectively, they produced (and are still producing) a large quantity of curricula innovations, a substantial number of which are archived in the proceedings of both the annual ASEE national meetings and the annual Frontiers in Education Conferences [17]. In addition, the NSF's Division of Undergraduate Education has funded a series of "Course, Curriculum, and Laboratory Improvement" (CCLI) projects, many of which are directed at improving engineering education. The NSF also funded a series of "Action Agenda" projects aimed at implementing and expanding many of the collations' innovations.

Concomitantly, a group of leading engineering deans and educators, realizing that the current ABET engineering criteria were stifling innovation, began the process with strong input from industry that in

1996 led to EC2000. Of note was the Accreditation Process Review Committee, chaired by John Prados (1991–92 ABET president), which condensed a large number of issues into a four-page report that stated "the current criteria are too long and by their very nature, encourage a rigid, bean-counting approach that stifles innovation, even though the Engineering Accreditation Committee sincerely tries to avoid this" [18]. In commenting on the newly adopted criteria, Prados noted that the major drivers had included a shift from defense to commercial competition with a resultant impact on engineering employment, the exploding information technology growth, corporate downsizing, outsourcing of engineering services, and the globalization of both manufacturing and service delivery. Employers were now emphasizing that success as an engineer required more than simply strong technical capabilities; also needed were skills in communication and persuasion, the ability to lead and work effectively as a team member, and an understanding of the non-technical forces that affected engineering decisions. To do this would require a new engineering education paradigm built around active, project-based learning, horizontal and vertical integration of subject matter, the introduction of mathematical and scientific concepts in the context of application, close interaction with industry, broad use of information technology, and a faculty devoted to developing emerging professionals as mentors and coaches rather than all-knowing dispensers of information [19]. Not surprisingly, these new criteria were consistent with the collective recommendations of the reports that preceded it.

III. WHY THE PROFESSIONAL SKILLS ARE PARTICULARLY IMPORTANT NOW

After ten years, these same drivers—rapidly changing technology, particularly information technology, corporate downsizing, outsourcing, and globalization—that provided the impetus for the professional skills are, if anything, even more critical today. This is especially true as industry views an increasingly larger portion of the science and engineering labor pool more like a commodity then a profession. Consequently, a growing number of less developed countries, with lower wage rates and an abundance of young, intellectual capital are competing for work that less than four years ago was performed by highly paid U.S. professionals, many of whom were then in short supply. While we do not know the extent of this shift in work from the United States (and other G-8 nations) to offshore locations, we do feel that the trend is, for the most part, permanent and irreversible. Hence, a new issue confronting engineering educators today is how to best ensure that our graduates will continue to bring value to a marketplace in which their salary demands are three to five times greater than their international competitors.

Oberst and Jones put the question succinctly: "[It] is no longer just whether engineers are being treated as commodities, but how engineers and other highly educated technical people shape and are shaped by the emerging realities of a truly global workforce. Engineers as a professional group are thus the canaries in the mineshaft of the new world economy. Whether engineers manage the transition from local to international workplace environments will determine if the profession remains attractive" [20].

They cite four major mega trends that affect the practice of engineering and necessitate the acquisition of more than technical skills:

- changes forced by the fragile world economy;
- student and professional mobility;
- use of communications and instructional technology; and
- increasingly loud voice of the social imperative.

To them, the so-called "soft skills" are much more than public speaking, management skills, and the ability to work well in teams. What is also needed is an understanding of how the growing social consciousness around the world is making it imperative that engineering students understand the implications of their work [21].

We propose that the mastery of these professional skills combined with an ability to innovate will add sufficient value to U.S. engineering graduates so that price does not become the primary determinant of who is hired in the global marketplace. From continuing skill development through lifelong learning that prevents technical obsolescence to the ability to do engineering within its global (and/or societal) context, the professional skills are critical.

Hence, globalization, which now includes the globalization of the engineering profession, is forcing us to reconsider the role of future engineering graduates and the education required to meet that role. In 1994, Morrow (then National Academy Engineering president) in a farsighted consideration of the issues facing undergraduate engineering education noted that it is not a given that the U.S. engineering education system will always be globally pre-eminent. There is clear evidence that many U.S. corporations now seek their engineering talent wherever they can find it throughout the world. Engineering design quality, low-cost engineering services, and responsive engineering production capabilities are determinants of where engineering jobs will be. U.S. construction companies use civil engineers in Korea; automobile companies use design talents in Europe; software companies use software engineers in India [22].

A decade later, it is now evident that countries like China and India, with large, well-educated work forces, have learned how to move large segments of their populations into the advanced industrial economy in a manner similar to Japan, Korea, and Taiwan before them. Further, like Korea and Taiwan, they are continuing to build universities to produce larger numbers of engineering and science talent and hence attract additional foreign direct investment, acquire advanced technology, and pursue export-led growth strategies [23].

Further, another trend from the early '90s will continue to impact engineering education—an increasing number of engineering graduates may never practice engineering; rather, they choose to use their engineering education to enter a wide range of fields from business, medicine, law, and management among others. Hence, as some have predicted, an undergraduate engineering education may become the liberal arts education of the twenty-first century [24]. Certainly, the increasing number of engineering schools introducing general or interdisciplinary degrees recognize this.

Consistent with this trend, Purdue recently created the country's first Department of Engineering Education [25], followed a few months later by Virginia Tech's creation of the second department [26]. Purdue's new department combines its existing freshman engineering and interdisciplinary engineering programs. In the future, it plans to offer graduate degrees for students studying the science of learning and other topics in engineering education. There also are plans to add an engineering teaching certification program for high school teachers and to pursue accredited undergraduate degrees in engineering education and interdisciplinary engineering. Virginia Tech has similar plans for its program. Further, six states—Massachusetts, Arkansas, New Hampshire, Florida, Texas, and Maryland—have mandated engineering coursework in high schools, a trend that is likely to spread to other states in the coming years.

IV. PROCESS AND AWARENESS SKILLS

It is against this setting that we consider how to best teach and assess these professional skills. We believe that mastering these skills will be a major determinant of the future competitiveness of U.S. engineering graduates, enabling them to become highly innovative global "problem solvers," which, in fact, we propose is what much of engineering is all about.

To best examine these skills we have divided them into two categories: process skills—communication, teamwork, and the ability to recognize and resolve ethical dilemmas (a more advanced formulation of criteria 3.f) and awareness skills—understanding the impact of global and social factors, knowledge of contemporary issues, and the ability to do lifelong learning. We designate the first set as process skills because students learn a robust process to address each one. In contrast, the awareness skills are so designated because students learn how to be aware of the importance of each one and to include them in their problem-solving activities. In reviewing these skills, we cite examples of how some institutions are able to successfully teach them. Section V then summarizes how they are being assessed.

A. Process Skills

1) Communication (3.g): We note that communication is the one skill that can certainly be taught and assessed. Indeed, most universities have departments of communications. The proceedings of both the Frontiers in Education conferences and the annual conferences of the American Society of Engineering Education are replete with examples of ways to integrate communication into the fabric of undergraduate engineering education. We are particularly impressed with those institutions now combining communication with global and social and ethical issues as part of design projects. Two noteworthy examples are Union College and the University of Utah.

At Union College, Spinelli has developed a course that examines the history of electrical engineering by combining the study of technological development within American and European civilizations with a concentration on writing, oral communication, and ethics. Certainly, placing technological developments within a social and human context is one way of approaching ABET's engineering criteria for ethics (3.f), communications (3.g), and broad education (3.h), in a course with significant technical content [27]. In a similar spirit, faculty at the University of Utah are using funding from the Hewlett Foundation to bring together communication, leadership (team building), and ethics into the College of Engineering's eight programs over the entire four-year curriculum. They are building upon a successful model communication program in mechanical engineering, where teaching assistants from the humanities have been brought into the engineering classes so that communication skills can be taught as "situational" learning. A similar ethics component is to be added [28].

2) Functioning on multidisciplinary teams (3.d): More and more engineering courses are being designed to give students the opportunity to experience teamwork firsthand. These range from short, decision-making exercises to project management or business simulations lasting the length of the course. This team-based course design trend reflects industry practice, where teamwork has become the prevalent mode. Companies use teams as an integral part of their product development, process improvement, and manufacturing activities. Such management techniques as concurrent engineering, total quality management, and business process reengineering are founded upon the concept of people working effectively in teams. Engineering educators, recognizing these trends, are designing more and more courses around teams. Such programs as Columbia's Gateway design course [29], MIT's undergraduate design course and its "New Products Program" [30], and Rowan University's Engineering Clinics Program [31] make extensive use of teams composed of students, faculty, and outside sponsors. These project-driven classes provide students with the opportunity to experience team design work from idea conception to completion. When properly structured, such courses can teach students the skills necessary to work effectively in teams.

However, too often educators incorporate student teams into their courses with little thought to their best use. Minimal guidance is provided to students on group development, soliciting member input, consensus building, resolving conflict, and team leadership. Evaluation oftentimes is subjective and little more than a piecemeal integration of individual and group-level performance. Consequently, instructors often fail to capitalize on much of the learning that can occur through group dynamics and behavior [32].

However, there are several outstanding examples where engineering educators have integrated teamwork and team skill-building activities into the classroom. An increasing number of engineering educators now realize that students cannot be thrown into team projects without support. One of the primary methods created to help integrate team learning into the engineering classroom is the development of formal curricular modules that can be used by various faculty planning to have students work on team projects. Of note is the Clark School of Engineering, University of Maryland modular team training program—Building Engineering Student Team Effectiveness and Management Systems (BESTEAMS) [33]. Supported by the National Science Foundation, the goal of this program is to provide a team curriculum that can be easily adopted by engineering faculty from various schools and at different levels of the undergraduate curriculum. This well-structured program allows faculty to select from various modules, depending on the nature of the course and the knowledge level of the students. Its three modules—introductory, intermediate, and advanced—cut across three major team skill domains—personal, interpersonal, and project management.

The engineering schools at both the University of Tennessee and the University of San Diego have adopted this modular approach to provide engineering faculty with the tools necessary to develop students' team skills [34]. The underlying foundation of these training modules is based on learning style theory, enabling student problem solvers to apply newly acquired technical skills more effectively by improving interpersonal interactions. All levels of undergraduates have used these modules, which can be customized based on developmental level and technical knowledge of the student. The modular nature of all three programs makes them easily transportable in full or in parts, thus allowing faculty to customize based on class structure, project design, and course material.

Another key component for teaching students team skills is the type of team project students will be exposed to in the classroom.

Recent literature is replete with examples from structured, simulated team experiences to authentic design projects, where students work on real problems for actual clients [35, 36]. As discussed later in this paper, there is now an emerging interest in using projects with global and/or humanitarian dimensions.

Several experiential activities can help students better understand the behaviors and skills needed to be an effective team member. At one end of the spectrum, there are literally hundreds of "off-the-shelf" group exercises designed to give participants hands-on experience. On the other end, there are many elaborate game simulations designed to provide realistic conditions that allow students to experience teamwork. The choice of team task depends on the educational objectives. For example, if the objective is to have students experience a specific aspect of teaming such as brainstorming, specific group exercises in which students practice common methods of group brainstorming to generate new ideas can be used. However, if the objective is for students to experience a broad range of team processes and behaviors, then more complex activities are suitable. Two guiding principles should be followed in choosing activities: fidelity and complexity.

Fidelity is defined as the similarity of the training situation to the students' present and future working conditions. The higher the fidelity, the more superior the transfer of learning to the workplace [37]. The fidelity of a particular activity can be increased by matching the conditions of the work environment as closely as possible. This may be difficult, especially when it comes to physical conditions, but many of the environmental conditions can be simulated. An example is "temporal environment," which involves such factors as time limits and deadlines the team may experience. Research has shown that time has a definite effect on team performance [38]. Such conditions as actual time to complete the task or make decisions should be matched to real conditions where possible. "Social context" is another environmental condition that can be manipulated. Few teams work in a vacuum; instead, they typically co-exist with other teams that are working within a similar context. The more that inter-group activities can be designed into the team activity, the more a team can engage in real-world team behaviors such as inter-group communication, coordination, and conflict.

Complexity is defined by two subfactors: task interdependence and cognitive effort. The more complex the activity, the more team skills are required by the participant. Activities also can range from high to low degrees of complexity. In general, the higher the fidelity and complexity of the activity, the better the transfer of team skills to the workplace.

For example, programs like Purdue's EPICS [39] provides highly realistic teaming activities, with all the complexities experienced by a product design team. Some computer-generated simulations also can be both highly realistic and very complex. An example is the Center for Creative Leadership's COLAB simulation that places technology management students in cross-functional teams with a focus on making decisions on new polymer processes to be commercialized [40]. Each competing team's objective is to get the new process to the market in a timely manner. Students make decisions on the allocation of research and development resources, manufacturing processes, and marketing activities.

There are both advantages and disadvantages to each type of activity. Experiential activities categorized as high fidelity/high complexity most resemble real workplace" conditions, but typically are more difficult for the instructor to manage, resource intensive, and time consuming for the student. Activities that are lower in fidelity are typically more structured and easier to administer, but may be perceived as less relevant by the student, resulting in the experience having less of a learning impact. Finally, team activities that are lower in complexity may not challenge the team nor provide the environment necessary for intense interaction among team members.

3) Understanding professional and ethical responsibilities (3.f): As part of their educational process, students should be sensitized to the potential ethical dilemmas they may confront in their professional life. If an engineer is able to recognize a developing ethical dilemma, he or she should be better able to first clearly frame it and then begin the process of resolution. Stephan [41], in questioning whether or not engineering ethics can be taught, quotes philosopher Michael Davis in giving four good things that can result if successful: students can become more aware of the ethical implications of their work, they can learn ethical standards, they can become better judges of ethical conduct, and they can become more willing to put their ethical knowledge into action. To Stephan, the true test of engineering ethics education is how graduates behave in the workplace during their careers, certainly a difficult outcome to measure *a priori*.

Much attention has focused on how engineers perceive, articulate, and resolve ethical dilemmas that arise when complex, advanced technologies are developed, such as the explosion of the Challenger, the Three Mile Island Nuclear Power Plant accident, Cherynobl, the DC-10 cargo door, or the Ford Pinto [42, 43]. In fact, an entire field, disaster ethics, has emerged from studying such events [44].

While we believe that such lessons remain relevant to practicing engineers, of more importance may be how to recognize and then resolve those dilemmas that may arise in the routine practice of engineering. Engineers frequently work under cost and schedule pressures, situations that can lead to increased risk. At what point is that increased risk no longer acceptable? In addition, the multiple loyalties of the practicing engineer also contribute to ethical dilemmas. Certainly, engineers have a loyalty to their employer, but engineering practice typically also involves a client or contractor, creating a second level of loyalty. Then there is the public, where the "safety of the public" as declared by Cicero has become accepted as the responsibility of the engineer [45]. Every engineering code of ethics places the safety of the public in a prominent position. Finally, the engineer has a loyalty to the profession and to him or herself.

The need to incorporate some form of ethics instruction into the engineering curriculum is no longer debated, largely because of the new ABET engineering criteria. A number of educators have noted the important relationship between ethics and engineering design and the value of integrating the two within the curriculum [46, 47, 48, 49]. However, this is only a recent happening. Over the past fifty years, engineering educators have focused on providing students with tools and technical skills, but providing the education and skills for social decision making was not a priority. Consequently, until recently, little had been done to make students aware of the social dimensions of engineering [50]. Stephan found that only 27 percent of ABET-accredited institutions listed an ethics-related course requirement [51], even though an increasing number of philosophers, engineers, and ethicists focus their research and teaching on engineering ethics [52].

The interest of practitioners and professional engineering societies in engineering ethics has also increased. The Institute of

Electrical and Electronics Engineers (IEEE) has been especially active [53, 54]. However, if the vision for understanding ethical and professional responsibilities as articulated in ABET is to become reality, educators must now answer a number of questions: What is the appropriate content? What teaching methods and curriculum models are preferable? Which works best—required course, ethics across-the-curriculum, integration of ethics and science, technology and society, or integration of the liberal arts into the engineering curriculum [55]? Which outcome assessment methods are most suitable [56]? Pinkus has provided an overview of these issues with emphasis on biomedical engineering [57].

Pfatteicher [58] proposes that a current engineering ethics educational 'dilemma' is how to provide meaningful ethics instruction to all students without overburdening faculty, increasing graduation requirements, or removing essential technical material from the curriculum. She notes that the ABET engineering criteria call for ensuring *understanding* rather than *demonstrating* that graduates are ethical. Hence, students should be evaluated on knowledge and skills, not values and beliefs. Pfatteicher proposes providing students with an understanding of the nature of engineering ethics, the value of engineering ethics as opposed to the values of an ethical engineer, and the resolution of ethical dilemmas.

At the University of Virginia, Richards and Gorman have effectively used case studies to teach not only design, but ethics. They have developed (researched and written) a set of case studies for teaching engineering ethics, engineering design, and environmental issues. These cases have been used in a course on invention and design and in other courses offered by the Division of Science, Technology, and Society, which Gorman chaired. They emphasize that cases promote active learning, team-based activities, and the ability to deal with open-ended problems. With cases, students can be exposed to realistic situations involving unstructured problems with multiple possible answers, key decision points, and trade-offs. The case method, which also fosters the development of higher-level cognitive skills, enables students to address problems that require analysis, judgment, decisions, perspective taking, role playing, independent thought, and critical thinking [59].

B. Awareness Skills

1) Broad education to understand the impact of engineering solutions in a global and societal context (3.h) and knowledge of contemporary issues (3.j): A growing number of engineering programs recognize that these two areas can be combined with issues related to globalization, sustainability, and development, especially in lesser developed countries, and are designing highly innovative educational programs to meet this need. By introducing design projects into the mix, often as part of a service learning experience, they are finding effective ways to teach the gamut of professional skills while reinforcing the "harder" technical skills. We highlight some of these exemplary programs in this section, with a particular emphasis on those with a global orientation. While traditionally few engineering students study abroad or co-op/intern abroad—the most recent data indicate that only 4,670 students (2.9 percent) participated in a study abroad program in 2001–02 [60]—as noted here, this should change as innovative programs are designed to provide engineering students with needed global and social experiences.

Lucena, one of the first academics to study globalization from an engineering perspective, notes that corporations, governments, and the engineers they hire face increasing challenges, such as mobility of capital and labor, organizational restructuring across national boundaries, and the development and implementation of more efficient production and manufacturing practices, among others. Globalization depends on the availability of flexible workers to produce "just-in-time" products according to consumer demands and on the rapid dispersal of those products around the globe. This flexibility, demanded by globalization, presents special difficulties for engineering education and practice [61]. Most engineers have no choice but to learn to cope with the practices changes that globalization is creating. Lucena (who holds a B.S. and M.S. in engineering and a Ph.D. in anthropology) suggests that a more appropriate education to prepare engineers to deal with the challenges brought by globalization might be a liberal-arts-based education that teaches them first to recognize and deal with the political dimensions of their work and second to deal with the ambiguity that results from working, sharing, and even valuing perspectives other than their own.

Swearengen et al., concerned with outsourcing capturing an increasing percentage of engineering work, suggest that engineers will become "free agents" in a professional services market. To thrive, future engineers will have to be able to work productively with radically different cultures, educational backgrounds, technical standards, quality standards, professional registration requirements, and time zones. The manufacturing engineer must not only master the elements of global design, manufacture, marketing, and distribution, but also prepare to participate as a contractor in a "twenty-four-hour virtual enterprise" [62].

Engineers must understand that in a global context, engineering solutions, whether consumer products or unintended consequences such as resource exhaustion and environmental pollution, increasingly cross or transcend international boundaries. Global sustainability, for example, may eventually outweigh technical and other aspects of manufacturing.

Engineering faculty are beginning to recognize that students who have participated in study abroad programs are better problem solvers, have strong communication and cross-cultural communication skills, and are able to work well in groups of diverse populations and understand diverse perspectives. Living overseas creates graduates who are more adaptable to new environments and have a greater understanding of contemporary issues as well as engineering solutions in a global and social context [63]. However, further research is required to fully support these findings.

Perhaps the prototype model for integrating international experience into an engineering education is the University of Rhode Island's (URI) International Engineering Program. Founded in 1987 by John Grandin, professor of German, and Herman Viets, then dean of engineering, this innovative program combines an undergraduate engineering degree with a degree in languages (initially German, but now expanded to French and Spanish). In addition, students do an internship in a country where they must use their language skills, and many also do at least one term of study in that country [64, 65]. This five-year program, which has been replicated by both the University of Connecticut and Rice University, has served to increase both the quality and quantity of URI engineering students; currently 20 percent of incoming students participate.

Worchester Polytechnic Institute (WPI) is one of the leaders in enabling its students to study engineering within a global and social context [66]. WPI's program is centered on the Major Qualifying Project—the equivalent of a nine-credit capstone design experience—

and provides a professional-level application of the students' knowledge in their major fields. It typically involves the design, synthesis, and realization of a solution to a real-world technical problem. WPI has established project centers, including ones in Ireland, Denmark, Hong Kong, Australia, Namibia, and Costa Rica. By 2002, 35 percent of the electrical and computer engineering students were completing their senior design project in a project center (10 weeks). In total, more than half of the WPI students complete at least one degree requirement internationally. To make the programs more affordable, WPI provides free passports and financial aid incentives.

The University of Michigan [67] has created a global concentration in engineering with an initial focus on China, the United Kingdom, and Mexico. The flexible framework enables all disciplines to participate. It requires international experience, global engineering course content, and a required cross-cultural course for engineers on global understanding. A motivation to establish the program was to better prepare engineers to deal with the global supply chain by training engineers who possess not only the appropriate technical skills but also the cross-cultural skills based on knowledge of "other" cultures and their own cultural biases.

Michigan faculty have also created an Engineering Global Leadership Honors Program, where students select a regional focus and concentrate their humanities/social science electives in that area. Students also must complete two years of advanced language study. Teams of business and engineering students consult for a major corporation. Muzumdar and Bean feel that even though almost all business is conducted in English and students may not even work in a location where their second language is spoken, having a second language makes the student more likely to work well in any other culture.

Melsa, Holger, and Zachary have described Iowa State's Global Academic Industrial Network (GAIN), which provides U.S. students with international experiences in Germany to better prepare them for future job requirements [68]. They note that the critical element in all international exchange programs is the faculty; institutions must find ways to engage their faculty in international experiences, including extended stays at a foreign institution. Programs built around a single faculty member and his or her international connections are fragile and typically fail when that individual loses interest or moves. Further, funding cannot become the limiting factor with such programs. Institutional support at the highest levels is essential.

A promising, comprehensive program is Purdue's Global Engineering Alliance for Research and Education (GEARE). This unique eighteen-month program, developed in partnership with Karlsruhe (Germany) and Shanghai Jiao Tong (China) Universities, integrates language education, cultural orientation, three-month domestic and three-month international internships at the same partner firm, study abroad, and a two semester face-to-face multinational design team project, with one semester abroad and one at home. The bilateral program involves equal numbers of students from each university participating in the paired exchanges [69, 70].

Another model program for providing international experience is Old Dominion University's cluster concept. Here, students take a three-course cluster with an international perspective, including two required courses—"Global Engineering and Project Management" and "Communications Across Cultures"—and select one other from among "World Resources," "International Business Operations," or "Sustainable Development" [71]. The cluster concept attempts to provide students with a basic understanding of the integrative nature of successful engineering practices that involve not only technical but international, cultural, communication, and business factors. It also attempts to provide students with the knowledge to work productively in an environment that encompasses different cultures, business practices, resources, communication, and engineering practices.

The University of Kentucky has created an innovative combined B.S. Engineering—M.B.A. program with a strong international component directed at producing manufacturing engineers and engineering managers [72]. The engineering undergraduate degree, coupled with the M.B.A., allows students to explore immediate interests while building a solid, long-term career foundation. This integration of business and economics courses with a traditional engineering program over a five-year period results in students developing a broader, more holistic view of management principles and their application to an engineering environment. The students' senior year marks the beginning of the graduate M.B.A. courses and interaction with non-engineering M.B.A. students. During the summer prior to the fifth year, students participate in a study abroad program designed expressly for the program, thereby enhancing and broadening their cross-cultural experiences.

For the summer of 2004, the Kentucky students participated in a second innovative initiative—the University of Pittsburgh's Manufacturing and the Global Supply Chain in the Pacific Rim as part of the Semester at Sea Program [73]. That program, a joint effort between the University of Pittsburgh's School of Engineering and the International Business Center, offered three manufacturing courses with a global perspective as students visited China, Hong Kong, Japan, Korea, Russia, Taiwan, and Vietnam. Visits to in-country manufacturing sites complemented the class activities.

Amadei at Colorado has become a leader among the engineering educators now looking at sustainability issues in the less developed world. He suggests that most past engineering achievements have been developed with little consideration of their social, economic, and environmental impact on natural systems. In many instances, engineering projects have contributed to the degradation of the Earth's natural systems. Amadei is concerned with the education of engineers interested in addressing the problems that are most specific to developing communities—water provision and purification, sanitation, power production, shelter, site planning, infrastructure, food production and distribution, and communication. These problems are not usually addressed in U.S. engineering curricula, despite the fact that 20 percent of the world's population lacks clean water, 40 percent lacks adequate sanitation, 20 percent lacks adequate housing, and 30 percent live in conflict zones, transition, or situations of permanent instability [74]. As a result Amadei is helping to create a program in Engineering for Developing Communities that will view the developing world as the classroom of the twenty-first century. This interdisciplinary effort will bring together engineering and non-engineering disciplines, thus supporting the learning of multiple professional skills. It will address a wide range of issues—water provision and purification, sanitation, health, power production, shelter, site planning, infrastructure, food production and distribution, communication, and jobs and capital for various developing communities. The first phase involves an undergraduate certificate program that should be in place by the time this article is published.

As part of this initiative, Amadei and his colleagues have formed Engineers without Borders-USA (EWB) at Colorado, which is dedicated to helping disadvantaged communities improve their quality of life by implementing environmentally and economically sustainable engineering projects while developing internationally responsible engineering students. Student projects that involve the design and construction of water, sanitation, and energy systems are ongoing in Belize, Mali, Mauritania, Nicaragua, Peru, Haiti, and Thailand. Rowan University faculty are incorporating EWB projects into their junior and senior clinics as a means of introducing open-ended problem solving in conjunction with developing synthesis, analysis, teamwork, communication, business, and entrepreneurial skills [75].

A somewhat similar program is being developed at Colorado School of Mines (CSM), with a focus on "humanitarian engineering." With support from the William and Flora Hewlett Foundation, the goal is to nurture a cadre of engineers that is sensitive to social contexts and committed and qualified to serve humanity by contributing to the solution of complex problems at regional, national, and international levels and locations around the world. This goal is to be achieved through the development of a humanitarian component for the CSM engineering curriculum that will teach engineering students how to bring technical knowledge and skill, as well as cultural sensitivity, to bear on the real-world problems of the less materially advantaged [76].

A complement of Engineers without Borders—U.S.A. is Engineers for a Sustainable World (ESW) (previously known as Engineers without Frontiers—USA). ESW originated in the College of Engineering at Cornell University in 2001 as a result of the efforts of Dr. Krishna S. Athreya, director of Minority and Women's Programs in Engineering, and Regina R. L. Clewlow, a Cornell University graduate. ESW is based on the belief that engineers and community members can work together to identify and solve technology-based problems, employing solutions that can be locally sustained, leading to an improved quality of life. ESW believes that locally sustainable engineering solutions are fundamental to the needs of communities in which issues such as lack of clean water, poor housing, and limited energy are barriers to adequate living conditions. By establishing a national network in the United States for engineers to be of service to developing communities, ESW contributes to a better world and enriches the lives of engineering professionals who seek to participate in socially responsible endeavors. ESW has almost twenty chapters, with another thirty in the formation stage [77].

Iowa State University and the Universities of Dayton and Seattle have joined together to form Engineers in Technical, Humanitarian Opportunities of Service Learning (ETHOS). Its purpose is to help students gain an awareness of the social and cultural fabric of the poorest of the world and perform design research focused on improving the ability of these individuals to meet their basic needs. Engineering activities are being implemented in a number of formats, ranging from classroom activities to multi-semester research studies. Both on-campus curricular and immersion service experiences are included in its mission. Initial projects have focused on two non-governmental organizations' efforts to develop more efficient and more durable wood-burning stoves used for cooking by the world's poor [78, 79].

Another example of service learning incorporated as part of undergraduate engineering education is the building of low-cost, energy-efficient houses in South Africa by students from Tuskegee University and the University of Fort Hare (South Africa). The idea behind this project is to develop a way for some of the economic benefit to stay in the local community [80].

A number of faith-based institutions, notably Calvin, Drodt, Grove City, and Messiah Colleges, have combined engineering, service learning, and globally based humanitarian projects, thus meeting both social and student needs [81]. However, Riley and Miller (Smith College) have raised concerns about involvement with faith-based projects, feeling that certain projects may be inappropriate if the development aid is tied to religious conversion and destroying indigenous cultures without regard for the community's traditions [82]. Smith College has developed an interdisciplinary project-based course that seeks to initiate critical study of the technological, cultural, and policy aspects of international development. This course requires students from different majors to share sophisticated disciplinary knowledge. Students address the promises and limitations of technology for development; the meanings of capitalism, colonialism, and globalization; and the implications of engaging in development work from places of privilege. In developing a service component for the course, they seek to avoid sending students for only a few weeks to a country with which they have had no prior cultural experience—a situation that would make it difficult for students to acquire an adequate knowledge or sense of the community in which they are working.

Since the mid-1990s, an increasing number of programs have incorporated international design team experiences, involving students from a U.S. and one or more partner international institutions. The original concept involved using the Internet and e-mail for communication, with the team coming together at the end of the project for a final meeting and presentation. Now, with the introduction of virtual design and virtual teaming concepts, the potential exists to do these types of programs without having students leave home.

The need to train engineers to be well prepared to collaborate with their colleagues around the world and to work effectively in geographically distributed, multicultural teams was a motivation for Union College's creation of an International Virtual Design Studio (IVDS) in 1996. The IVDS initially brought together the mechanical engineering departments at Union College and Mideast Technical University (METU) in Ankara, Turkey, in response to the need to develop skills among students to better function in the emerging global environment in today's workplace. In 1997, Queen's University (Kingston, Ontario) joined the partnership. Such projects provide international culture interaction, team building, communication, creative thinking, and project management experience. Each IVDS team has four to six members, two or three from each institution—METU and either Queens or Union. At Union, students select their project in spring term of the junior year. Students must analyze, design, and build an autonomous robot for a given task and application. Since 1999, METU students have visited in November to compile and finish design reports. Final reports are presented before they leave. In January, after a prototype has been built, they go to Turkey for a competition at METU [83].

Sheppard et al. propose that virtual reality (VR) has the potential to have a major impact on engineering education by permitting students to explore environments that would be otherwise inaccessible. Specifically, VR will better facilitate teaming on an international and therefore multicultural level. Hence, faculty now must address educational collaboration in the virtual environment, testing and refining it at the institutional level, between institutions and across national boundaries. A pilot implementation at Stevens Institute of Technology involves undergraduate student teams from three universities in three countries: Stevens is providing overall design and project coordination, the University of the Philippines (Quezon City, Philippines) is the manufacturing lead, and the National Institute of Technology (Warangal, India) is the simulation lead. The project, "MEMS across the Globe" forms part of a larger pilot in virtual student design undertaken by a consortium of schools in collaboration with PTC Inc., a producer of industry standard design and collaboration tools [84]. At Northern Arizona, language and engineering faculty are combining to utilize virtual reality to develop a pilot "Global Engineering College." When successfully implemented, it will inject international perspectives throughout the curriculum by leveraging technological developments to create a "virtual" engineering college [85].

2) A recognition of the need for and the ability to engage in lifelong learning (3.i): Although the new ABET engineering criteria have brought lifelong learning to the forefront of engineering education, as Litzinger [86] and his colleagues have pointed out, lifelong learning in engineering has been recognized as critical for decades. They note that the *Final Report of the Goals Committee on Engineering Education* (1968) contained a discussion of the importance of lifelong learning [87], and the theme of the 1978 ASEE Annual Meeting was "Career Management—Lifelong Learning." A number of earlier studies that investigated the types of activities involved in lifelong learning, their frequency of use, the support systems required, the barriers, and impact of lifelong learning for individual engineers are summarized in a 1985 report by a National Research Council panel [88]. Litzinger and his colleagues, who are at the frontier of studying lifelong learning relative to engineering education, note that a major issue is how to assess the extent to which students are prepared to engage in it and also their willingness to do so [89, 90, and 91]. With funding from the National Science Foundation, they have been investigating how best to assess lifelong learning.

Various engineering education researchers have defined elements of lifelong learning, including Henry and Rogers [92], whose RIRI model consists of four components: receiving, inquiring, reflecting, and integrating. Miller, Olds, and Pavelich purport that their Cogito system for measuring intellectual development (based on assessing reflective judgment) will, when fully validated, also assess lifelong learning [93]. When we specified the attributes of lifelong learning as part of our NSF-funded Action Agenda study [94], we proposed that these include the ability to:

- demonstrate reading, writing, listening, and speaking skills;
- demonstrate an awareness of what needs to be learned;
- follow a learning plan;
- identify, retrieve, and organize information;
- understand and remember new information;
- demonstrate critical thinking skills; and
- reflect on one's own understanding.

We propose that as students acquire the other professional skills, especially the other two awareness skills, as well as the process skills, that they will, in fact, acquire the ability to do lifelong learning. Hence, one will become a proficient lifelong learner as one becomes proficient in the broad spectrum of professional skills.

V. ASSESSMENT OF THE PROFESSIONAL SKILLS

Recent assessment efforts directed at the professional skills could best be described as encouraging, but with much work left to do. There have been important strides in developing rigorous assessment tools and conducting effective outcome studies for three of the skills: an ability to function on multidisciplinary teams (3.d), an understanding of professional and ethical responsibility (3.f), and an ability to communicate effectively (3.g). Yet, the literature remains sparse with respect to robust, effective measures for these outcomes. Further, we propose that three hurdles have impeded the development of viable tools to assess engineering students' attainment of the professional outcomes: a consensus about definitions, the scope by which the outcome is assessed, and the nature of the outcome itself.

For any evaluation activity, outcome definition (specification) and its engineering pedagogical context ultimately drive how it is assessed. It is clear that definitions of the "hard" outcomes have greater acceptance in the engineering education community than do those for the professional outcomes. Consequently, educators have a greater level of confidence (and certainty) in assessing these outcomes. For example, Olds, Streveler, and Miller [95] are developing a thermal and transport sciences concept inventory that will provide engineering educators with reliable feedback about a student's understanding (or misunderstanding) of the principles of thermodynamics and hence better assurance that students are capable of solving similar problems in practice. Since thermodynamics is a fundamental engineering science, the definition associated with this body of knowledge is known and accepted among engineering educators. (This is one of several concept inventories currently under development; see Evans [96] for a summary of the various inventories.)

To illustrate the problem with assessing the professional skills consider that Shuman et al. have developed and validated a scoring rubric [97, 98] to assess students' ability to evaluate and resolve ethical dilemmas (outcome 3.f). However, even if the student provides a creative solution to a posed ethical dilemma, there is no assurance that he or she could carry that solution to completion or behave in an ethical manner when confronted with a dilemma in practice. As a result, one does not obtain the same level of confidence that a student will ascertain and handle ethical dilemmas in engineering practice as one does with respect to thermal dynamics. Further, different faculty have provided varying definitions for what "understanding ethical and professional responsibilities" means (consistent with ABET's intent). Because engineering ethics is highly situationally dependent, the exact characterization for assessment purposes may be imprecise.

The second obstacle is the scope of the educational experience needed within the engineering program to master the outcome. Traditionally, "hard" skills are taught and acquired through specific coursework; hence, assessment of those outcomes can be largely limited to the coursework the student has taken. However, acquiring the professional outcomes may not result simply from participation in a particular class or set of classes. Rather, these outcomes are more often acquired or influenced through sources both in and outside the classroom, which is a further reason for the new emphasis on global and service learning. Thus, assessing a student's "ability to function on multidisciplinary teams" may be the culmination of several courses in which students are first exposed to the process of teamwork and then actively engage in various forms of teamwork through projects and homework, as well as activities outside the classroom, including projects, study abroad opportunities, internships and co-op assignments, and on- and off-campus extracurricular activities. Hence, properly evaluating outcome 3.d may require assessing all such sources. As discussed below, teamwork is one area where promising assessment tools are beginning to appear, including the Professional Developer, which, when completed, will allow for a comprehensive assessment by obtaining input from multiple sources (e.g., multiple student teams, employer(s), friends, instructor, etc.) [99].

The engineering education literature provides several examples on how to assess team skill development and project effectiveness. These include multisource feedback [100], often incorporating peer evaluation methods [101], and project rubrics [102]. Multisource assessment is a formal process that collects critical information on student competencies and specific behaviors and skills from several sources, including peers and instructors, as well as the student, and presents the collected information in a well-organized format so that he or she can better understand both his or her personal strengths and areas in need of development. The typical process involves gathering evaluative information on a target student from two or more rating sources. The target student also provides self-ratings that are subsequently compared with those from the other sources. Once all ratings are complete, the student receives feedback on the behaviors, skills, and performance being assessed. The student then can interpret the results and make personal decisions on actions that should be taken based on the information received. Current research indicates that these assessment processes not only provide valuable data on learning outcomes, but also have an impact on learning itself. For example, introducing a formal assessment process helps reinforce the learning objectives established for a specific course. When students are actively involved in their own assessment, they are forced to think about their learning in profound ways. Further, if the process is repeated over the course of a semester or several semesters, important learning and self-improvement can occur.

Growing evidence shows that feedback processes have a positive impact on student development of team skills. Consequently, several engineering schools have introduced multisource feedback processes as part of the coursework. Working in teams provides the opportunity to receive feedback from peers, teaching assistants, and faculty. Results presented in an earlier paper by McGourty [103] consistently demonstrated that students improved according to the perceptions of peers and faculty.

Peer evaluations, sometimes considered a subset of multisource feedback, are being readily applied in many engineering classrooms. Using typical peer rating systems, student team members confidentially rate how well they and individual team members are doing in fulfilling their tasks [104] or individual behaviors [105]. Some researchers [106] maintain that peer evaluations can support grade adjustments by faculty because student team members are in a good position to evaluate individual contributions to team projects.

Scoring rubrics are specific project-related attributes rated using checklists by a panel of experts, often consisting of faculty, alumni, and other industrial partners [107]. A number of engineering faculty have developed rubrics to measure team effectiveness in terms of product or project performance. Team project performance has been rated in such areas as product or process design effectiveness, innovativeness of the overall design, and effective presentation by the team.

When EC2000 first emerged, an accompanying white paper called for the development of multiple assessment tools to assist in evaluating engineering program quality [108]. The white paper indicated that multiple methods should be used to measure each outcome and that such methods as portfolios and video presentations are better able to assess higher-level cognitive, affective, and behavioral abilities. Prus and Johnson [109] have proposed six types of methods—tests and examinations, measures of attitudes and perceptions (self- and third party reports), portfolios, competency measures (performance appraisals and simulation), behavioral observation, and external examiner—that can be used to assess one or more of the professional skills. However, as Prus and Johnson purport, there is a consistently inverse correlation between the quality of the measurement methods and their expediency. The best methods usually take longer and cost more in terms of faculty time, student effort, and money. Portfolios, along with performance appraisals and behavioral observations, offer the most comprehensive information for measuring many outcomes and are conducive to evaluating professional skills. Together with behavioral observations, these three methods may yield the most comprehensive information when measuring the professional outcomes. As for outcome 3.g, an ability to communicate effectively, portfolio analysis coupled with rubrics [110, 111] provides a consistent, feasible, and accurate approach for its assessment [112–114]. Other effective methods also can be found in the literature [115, 116].

Performance appraisals [117–119] are competency-based methods (also commonly referred to as authentic assessments) used to measure pre-operationalized abilities in a real-world-like setting. Such an appraisal provides a systematic measurement, usually in the form of a rubric, for the demonstration of an acquired skill(s). In an educational setting, performance appraisals can be conducted on students in individual classes or for a particular cohort of students. This is a valuable assessment methodology because it can provide a direct measure of what has been learned in a course or program of study. Further, because it goes beyond the typical paper-and-pencil approach common to other assessment methods, a performance appraisal is suitable for measuring such behaviorally based skills as evaluating an ethical dilemma or working on teams. Engineering courses offer ample opportunities to include performance tasks as part of the course requirements. Such tasks might include client-based design projects, open-ended laboratory assignments, or the design and construction of manufactured articles. As noted, the rubric for ethics developed by Shuman et al. offers promise for engineering assessments, and there has been substantial work in other fields of study [120, 121]. In brief, portfolios and performance appraisals are a highly valued form of student outcomes assessment. However, they are costly to administer.

The third hurdle—nature of the outcome—revolves primarily around the "awareness" outcomes—those that hope to capture students' *ability to know how to be aware of the importance* of each one and to incorporate them into their problem-solving activities. These include the broad education necessary to understand the impact of engineering solutions in a global and social context (3.h), recognition of the need for and an ability to engage in lifelong learning (3.i), and knowledge of contemporary issues (3.j). These three outcomes focus on influencing engineering students' aims, attitudes, and values as they practice their engineering "hard" skills. There is no question that the engineering education community has begun to embrace these outcomes as important to the growth of the field. Still, to properly assess these outcomes, educators both within individual programs and across the engineering community must further grapple with the program's scope.

Once these obstacles have been overcome, the question that remains is this: if awareness skills are best acquired through various program elements, can they be effectively assessed? For example, in 1985 the National Research Council Committee on the Education and Utilization of the Engineer described several activities associated with lifelong learning [122]. Most of these activities are associated with continuing one's education so that the engineer's knowledge and skills do not become rusty. Merely asking graduating seniors or alumni if they plan to continue their formal education provides only a naïve surrogate measure of the lifelong learning outcome, since this assessment measures only one of its aspects. It is our belief that ABET's intention with lifelong learning is to go deeper than traditional post-baccalaureate education. From the engineering perspective, Flammer developed a model for successful lifelong learning that centers on two critical aspects: motivation and ability [123]. Similarly, Candy modeled lifelong learning from the perspective of self-directed learning focusing aspects into "will do" and "can do" skills [124]. Two potential instruments have been developed to measure self-directed learning: Guglielmino's Self-directed Learning Readiness Scale [125] and Oddi's Continuing Learning Inventory [126]. The former instrument has been in existence longer and thus has been widely validated [127]. It is available directly from the author [128].

Because the awareness skills center on students' attitudes and values, another plausible methodology may be to use behavioral observation [129, 130], an assessment technique for measuring the frequency, duration, topology, etc. of student actions, usually in a natural setting with non-invasive methods. Brereton et al. [131] propose that behavioral observations often provide the best way to evaluate the degree to which attitudes, perceptions, and values have been achieved. However, as with portfolios and performance appraisals, behavioral observations are costly to administer and evaluate. One promising method to combat the cost is to use work sampling methods that take advantage of probability theory to reduce the amount of time necessary to accurately behaviorally observe events or activities [132].

VI. CONCLUSION

To answer our original question: Can the ABET professional skills be taught? We answer with a qualified yes! Although not necessarily taught in the traditional lecture format, these skills can certainly be mastered as part of a modern engineering education format that utilizes active and cooperative learning, recognizes differences in learning styles, and is cognizant of teaching engineering in its appropriate context.

As we consider how to best teach the professional skills, or conversely, how students can most effectively learn these skills, we are positive about a new learning pedagogy that is emerging—service learning and its complementary component—global service learning. This provides both an opportunity and a challenge to engineering educators—to determine how to incorporate real-world experiences into the engineering curriculum while providing a valuable service for either a nonprofit organization, a disadvantaged community, or a rural village in a less developed country—and do it all without reducing academic content [133, 134]. We propose that if this could be done, then engineering faculty will have found a way to effectively integrate the learning of multiple outcomes into one comprehensive, educational experience, especially if the curriculum is now reorganized to point to such an objective. Hence, coursework at the first, second, and third years, including the integration of the humanities and social sciences in a well-thought out manner [135], would fully support a senior-year capstone design experience that would benefit both student and community.

As to our second question: Can these professional skills be assessed? Here, we again offer a qualified yes. Certainly elements of each are being assessed, but to varying degrees and with much work left to be done. The assessment challenges are greater, but we are encouraged by the number of investigators who are rising to this challenge.

ACKNOWLEDGMENT

This work was supported in part by NSF Grant DUE-0206630, "The Student Developer: Using 360-Degree Multisource Assessment for Student Learning and Professional Development."

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