The Attributes of a Global Engineer Project

Abstract

For the past several years, the American Society for Engineering Education’s Corporate Member Council, reflecting the voice of industry, developed a series of attributes representing the desired competencies needed by engineers in order to effectively live and work in a global context. A global online survey was launched to validate the performance and proficiency levels of each attribute, and a series of global focus groups in every major region of the world have been held for the purpose of clarifying and refining the attributes. In 2015, the Attributes of a Global Engineer Project formally concludes its work, having benefitted from prolonged engagement with and input from globally-representative stakeholder groups of academicians and industry partners. This paper will describe the process to develop attributes of a global engineer; present a summary of key results; discuss how attribute outcomes can assessed in engineering education globally; and provide recommendations for a variety of stakeholders, with particular emphasis on lessons learned from the multi-year Project.

Introduction and Context

The American Society for Engineering Education (ASEE) Board of Directors established the Corporate Member Council (CMC) to convey the ideas and views of corporations to ASEE. With over 120 corporate and non-academic institutional members, the CMC's mission is to foster, encourage, and cultivate the dialogue between industry and engineering educators. Its strategic goals are:

- Diversity in engineering education
- Enhancing the K-12 educational pipeline/future workforce
- Reforming engineering education
- Collaborating on engineering research and intellectual property
- Liaison with engineering, technology, and the Society

The CMC has several Special Interest Groups (SIGs), which exist to share information and advance key priorities of the CMC. The International Engineering Education SIG is the CMC sponsor of the Attributes of a Global Engineer Project.

The Attributes of a Global Engineer Project grew out of an expressed need by CMC members to identify and validate specific knowledge, skills, abilities, and perspectives that would be required of an engineer living and working in an increasingly global context. Specifically, the goal was to refine a list of attributes that would be applicable to engineers regardless of specialty, location, or background.

This paper contains the following sections:

- Project Overview
- Literature Review
- Initial Attribute Development and Refinement
Survey Research on the Attributes of a Global Engineer
Focus Groups and Workshops on the Attributes of a Global Engineer
Revised Framework for the Attributes of a Global Engineer
Conclusion
Bibliography

Project Overview

The Attributes of a Global Engineer Project’s principal goal is to:

“Enhance the employability of engineering graduates and increase the international competitiveness of ASEE’s corporate members, so that engineers can effectively live, work, and perform anywhere in the world.” (Diane Matt, Chair ASEE-CMC, 2014)

Key Milestones of the Project to Date

- Special Interest Group on International Engineering Education formed by ASEE’s Corporate Member Council (CMC) (2008-2009)
- Attribute conceptualization and development resulting in initial list of 48 attributes refined to a list of 20, informed from a literature review, the work of John McMasters from The Boeing Company, and a content analysis of CMC representatives’ job descriptions of globally-oriented engineers (2010)
- Survey translated into 13 languages and distributed worldwide through IFEES for attribute validation/prioritization (2010-2011)
  - Goal of survey was to establish importance and proficiency:
    - Upon graduation from secondary-level education
    - Upon graduation from college/postsecondary-level education
    - As an early-career engineering professional
- Initial dissemination of survey results at ASEE meetings (2011-2012)
- Strategy developed for the Attributes of a Global Engineer Management System (Appendix A)
- Philanthropic support received from The Boeing Company to support the Project (late-2012)
- Focus groups and workshops held to amplify survey results, create outcome-per-Attribute statements, seek additional input, and refine the Attribute list (2012-2014)
  - Focus groups and workshops held in USA, Latin America, Europe, and South Africa
- Forthcoming focus groups and workshops to be held in USA, Asia, and Middle East (mid-/late-2014)
- Additional dissemination (2015-onward)

Before describing research elements of the Attributes of a Global Engineer Project, it is necessary to place this work in its proper context. The next section is a brief literature review.

Literature Review: Context for Attributes of a Global Engineer Project
The Attributes of a Global Engineer Project is fortunate to be informed by and draw upon complementary work by other authors and thought leaders in engineering education. Thus, this literature review contains the following components:

1. Global Context for Engineering Work
2. Global Competence Frameworks in Engineering Education
3. Curricular Considerations to Prepare Global Engineers
4. Industry Involvement in Preparing Global Engineers

Global Context for Engineering Work

Over 20 years ago, Arango (1991) forecasted that all nations will be engaged in a global competition to advance their national welfare in a global economy, and that universities must prepare a U.S. engineer capable of both competing and collaborating with his or her foreign counterparts. Moran and Richard (1991) also asserted that the global economy is here to stay, and asked: What skills do technical professionals require to meet its demands? How must they interact across cultures to be effective? How can their needs be developed? In the intervening years, the world has seen significant advances in and adoption of new technology, political events that have led to the opening of formerly closed societies, economic policies that have encouraged free trade, and the growth in multinational companies. These changes have resulted in a world with increased connectedness and interdependencies and a globalization of the engineering workforce (Rajala, 2012).

Today, there are many different types of global corporations, many different strategies for doing global business, and many different structures for carrying out those strategies (McCall and Hollenbeck, 2002). As a result, engineers will increasingly work on a global basis and it is likely that global mobility will be a facet of employment patterns for some engineering professionals. An engineer is now working in a borderless world infused with collaborative technologies that have created the 24/7 office working 7 days a week, 24 hours a day. Companies are using skilled engineering teams dispersed around the world to develop products in a collaborative manner, rapidly migrating from local, cross-functional collaboration to a mode of global collaboration (Eppringer and Chitkara, 2006; and Galloway, 2003).

The emergence of global networks of innovation and the increasing distance between technology innovators and their markets requires engineering programs to reflect the new realities of global innovation, especially in preparing future engineers to be able to fully participate in the emerging global networks of innovation (Nambisan, 2005). In a global, knowledge-driven economy, technological innovation—that is, the transformation of knowledge into products, processes, and services—is critical to competitiveness, long-term productivity growth, and the generation of wealth. Preeminence in technological innovation requires leadership in all aspects of engineering: engineering research to bridge scientific discovery and practical applications; engineering education to give engineers and technologists the skills to create and exploit knowledge and technological innovation; and the engineering profession and practice to translate knowledge into innovative, competitive products and services (Duderstadt, 2010).
Bremer (2008) explains that enabling future engineers to be more competitive in their chosen career is one of the prime reasons that engineering education has to be more internationalized. Not only does a global perspective give future engineers an understanding of different cultures’ values, morays, and traditions, it makes them more effective businesspeople and better enables them to negotiate, supervise, and work side-by-side with others. Engineers need to be acquainted or at least aware with cultures for an adequate design of product and services for global markets. Consequently, they are required to work with multicultural (not just multi- and/or inter-disciplinary) teams, and to be geographically and/or virtually mobile (Callaos, 2008).

As engineers adapt to this global workplace, there is widespread recognition that nature and significance of global environmental challenges indicate engineers are likely to be called on to assume an increasingly important role in addressing needs and solving problems (Stokes, 1995). Indeed, engineers are being pressed to use the limited natural resources of the world to satisfy ever increasing human demands (Davidson et al., 2010).

Rugarcia et al. (2000) summarize what is happening in the context of engineering work: information is proliferating; technological development is multidisciplinary; markets are globalized; the environment is endangered; social responsibility is emerging; corporate structures: are becoming more participatory; and change is rapid. What is needed, they argue, are the following: independent learning, interdependent learning, and lifelong learning skills; problem solving, critical thinking and creativity; interpersonal/group/team skills; communication skills; assessment and self-assessment skills; integration of disciplinary knowledge; and managing change.

**Global Competence Frameworks in Engineering Education**

The future engineering professional has to be prepared to face a world of no borders extremely dynamic and competitive (da Rocha Brito, and da Brito, 1999; da Rocha Brito and Ciampi, 2000). Therefore, the skills, attributes, and competencies of the 21st century global engineer are significantly different and more complex than what has been needed ever before (Abdulwahed et al., 2013). The academic preparation of the global engineer is the next major wave of change that will confront engineering education programs worldwide. Unfortunately, most U.S. programs are not presently preparing their students well to enter the global marketplace (Lohmann, 2003; Mazumder, 2008; and Waggenspack et al., 2011).

Weichert, Rauhut, and Schmidt (2001) indicate that there is a strong consensus from many organizations, associations, and professional societies concerning the qualifications needed for the future global engineer. The problem, they posit, is in how to attain these ambitious goals. Lohmann, Rollins, and Hoey (2006), however, acknowledge that while there is broad agreement within the engineering community for the need to better prepare engineers for global practice, there is much less agreement as to what skills and abilities define global competence, what combination and duration of international education and experiences best instil it, and what means and metrics should be used to judge whether students have attained it. Finally, Johnston (2001) notes that there has been a tendency for the global reach and impact of engineering to be based essentially on North American or European perspectives.
Prados, Peterson, and Lattuca (2005) remind us that ABET requirements emphasize learning outcomes, assessment, and continuous improvement rather than detailed curricular specifications. These criteria, together with international agreements among engineering accrediting bodies, facilitate mobility of an increasingly global profession. Meantime, the Bologna process is considered a major revolution in European higher education, and it has motivated alterations, within higher education institutions, in the structure of degrees, in curriculum, in duration and in teaching and learning relationships. The main features are the creation a more homogeneous set of qualifications within Europe, including engineering degrees (Soeiro, 2006).

Relatedly, Lang et al., (1999) discuss the level of importance industry professionals place on attributes related to the eleven ABET program outcomes and assessment categories, noting that in developing engineering accreditation criteria, ABET reaffirmed a set of “hard” engineering skills while introducing a second, equally important, set of six “professional” skills (including communication, teamwork, understanding ethics, professionalism, engineering within a global and societal context, lifelong learning, and a knowledge of contemporary issues).

Elsewhere, two reports from the National Academy of Engineering (NAE), of the National Academies, entitled The Engineer of 2020 and its follow-on report, Educating the Engineer of 2020, were developed by two groups of distinguished educators and practicing engineers from diverse backgrounds. They were created in response to a concern that engineering students may not be appropriately educated to meet the demands that will be placed on the engineer of the future, without refocusing and reshaping the undergraduate engineering learning experience. Indeed, NAE urged university engineering schools in the U.S. to embed curriculum and assessment measures into academic programs that provide opportunities and associated assessment metrics to meet this international challenge. Specifically, NAE charges universities and colleges to prepare engineers that are leaders in global engineering fields with strong communication, leadership and interdisciplinary research, and professional skills in diverse in engineering environments (Whitman, Toro-Ramos, and Skinner, 2007).

The requirements for the global engineer are multifold and include having the basic and advanced engineering knowledge together with the international communication skills and experiences (Furuya, Bright, and Saika, 2008). Other researchers and authors have developed and presented various approaches to enhancing the global preparation of engineering students. Parkinson (2009) describes 13 dimensions or attributes of global competence that will position leaders of the future to manage and direct global engineering activities. Allan and Chisholm (2009) developed a framework of specific global competencies that takes account of race, ethnicity, culture, and language. They conclude that on-campus and work-based learning environments need to be fully integrated in order to realize the value of education–industry partnerships based on mutual trust and understanding. Furthermore, they urge engineering educators to be trained and developed to teach an understanding of competencies in the context of a global information society.

Shakhgildian and Fomin (2003) present a global engineer’s competence as an aggregate of knowledge, skills, and know-how, which are formed and improved during a student’s educational, professional, and social activities. The essential knowledge base must include a
thorough grounding in mathematics and natural sciences; a good understanding of the principles of engineering science; some knowledge of a specialist branch of engineering (e.g., electrical or mechanical); the elements of economics, business, and management; some education in environmental matters; and an introduction to ethics. The most important skills which engineering students need to develop during their education and training should include problem solving and design skills; communication skills; team working skills; and learning “how to learn.” Finally, experience working in an international team is highly desirable.

Hirleman, Groll, and Atkinson (2007) posit that engineering education is now comprised of three key axes: technical, professional, and global skills. Just as research has shown that the incorporation of professional skills can strengthen students’ technical skills, the expectation is that global skills can similarly enhance overall engineering curriculum outcomes. The engineering education system for the future should be broad-based engineering programs for easy mobility, flexibility, and adaptability to the new changing technology and environment (Nor, Rajab, and Ismail, 2008). This is especially salient, as societal changes and grand challenges require engineering professionals to have a global perspective, including greater dialogue and cooperation between the engineering and international development sectors across academia, government, business, and non-governmental organizations, including a greater knowledge and understanding of global development (Neal, 2005).

Research on student-learning outcomes indicates that university graduates do not possess important skills required by employers, such as communication, decision-making, problem-solving, leadership, emotional intelligence, social ethics skills, as well as the ability to work with people of different backgrounds. Today, engineering graduates are required to work within multicultural and multinational workplace environments, and thus need to possess adequate professional attributes and competencies (Nair, Patil, and Mertova, 2009). This corroborates seminal work undertaken by The Boeing Company, which for several years developed a set of desired attributes of engineers and ways for industry, government, and higher education to work together to assure an adequate future supply of well-prepared engineering graduates for the full range of employers who have need for such talent (McMasters and Matsch, 1996; McMasters, 2004).

Several authors note that engineering graduates need oral, listening, written, visual, interdisciplinary, and intercultural communication skills to maintain relevance in a global environment. This includes an emphasis on particular discipline-specific terminology required in the international professional engineering field (Riemer, 2002; 2007). Del Vitto (2008) suggests that engineering students need not only to develop foreign language proficiency, but must just as importantly develop cross-cultural, adaptive “soft skills” which will assist them in working collaboratively in a global environment.

Non-verbal intercultural communication skills and awareness are also important for the global engineer, because non-verbal communication is culture dependent. Ethnocentrism can provide a barrier to effective communication, particularly with regard to assumptions that all non-verbal signals reflect the individual’s personal cultural paradigm. Due to the complexity of non-verbal communication, misunderstandings can arise, including overt, covert, and latent forms. Thus,
engineers working in a global environment must express empathy, self-awareness, social skills, and intercultural awareness (Riemer and Jansen, 2003).

Globally-oriented engineers have the need to collaborate with people from many cultures; collect information about new cultures; design usable communication suitable for translation, globalization, and localization; and to be prepared to understand and deal with organizational change in a global context (Hovde, 2005; Lucena, 2006). One way to underscore the dynamic nature of engineering work is through experiential learning in courses to promote higher levels of learning, student engagement, and the global citizenship required for all engineers in the twenty-first century (Berndt and Paterson, 2009).

Finally, in this evolving world, a new kind of engineer is needed, one who can think broadly across disciplines and consider the human dimensions that are at the heart of every design challenge. The crucial question facing engineering education is whether we are adequately preparing our future engineers and designers to practice in an era that requires integrated and holistic thinking, or are needlessly limiting their solution spaces to those that contain only technological answers, with scant or passing consideration of the myriad other influencing and dependent factors (Grasso and Martinelli, 2010). All of this, naturally, has implications for curricular considerations to prepare global engineers.

Curricular Considerations to Prepare Global Engineers

Twenty-first century engineering graduates are expected to be skilled in a variety of competencies beyond the profession’s traditional technical skills. The employment requirements for mobility of engineers across the national boundaries have changed the traditional demand-supply perspective necessitating recasting of the engineering curricula. Globalization presents engineering educators with new challenges as they face the need for graduates who can function comfortably in an increasingly distributed team context which crosses country and cultural boundaries. This pressure to acquire professional attributes which transcend the solely technical domain places additional stress on traditional curriculum models. (Daniels, et al., 2010)

It has long been recognized that the engineering curricula need to be revised, and universities must make provision for engineering-oriented teaching and learning materials to be updated and capable of enhancing the skills and attributes of future engineers to meet the changing global environment (Nguyen, 1998). To better equip students to be successful global engineers, Savage, Stolk, and Vanasupa (2007) encourage the design of curricula that promote awareness of the broader impacts of engineering, enhances systems thinking, reflects sustainable engineering practices, and helps prepare students to make an impact in the global community.

Globalization at once draws our attention to the increasing connectivity between what is local and global, while highlighting expanding divides between dynamic growth in technology and poverty, injustice and human suffering in developing communities. Recent discussions in engineering has also focused on the importance of preparing students for a global future, and it has given rise to a recent trend in engineering education involving project-based courses in global development, often connected with projects overseas (Riley and Bloomgarden, 2006).
Zandvoort (2008) echoes the importance of preparing engineering graduates for socially responsible decision making and conduct in a global context.

The practice of engineering requires a broader perspective than is available in many current curricula; emerging engineers must recognize their role, not merely as developers of new technological systems, but also as educated, informed, and ethical servants of society with a higher purpose (Moore and Voltmer, 2003). An engineering curriculum that fosters community engagement can help engineering students acquire many of these additional abilities, such as teamwork and cross-cultural communication, while at the same time helping the profession achieve its broad goals of improving the quality of life (VanderSteen and Mushtaq, 2010).

Downey et al. (2006), in work on testing the global competency of engineers, explain that a goal of working effectively with different cultures is fundamentally about learning to work effectively with people who define problems differently. They note that integrated classroom experiences designed to support global learning enables larger numbers of engineering students to take the critical first step toward global competency.

Doboli, Doboli, and Currie (2009) describe an educational approach involving students from multiple international universities that seeks to emulate the main elements of global engineering teams that develop complex, multidisciplinary designs while targeting market-related constraints, such as price, reliability, size and ease-of-use. Meantime, a Global Engineering Emphasis package, developed by Vohra, Kasuba, and Vohra (2006), contains modules dealing with language expectations, communication skills, multiculturalism, sensitivity issues, and engineering related global issues in societal, engineering, and business fields.

Engineering faculty are also 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 (Shuman, Besterfield-Sacre, and McGourty, 2005).

Curriculum changes focused on introducing educational experiences to develop attitudes and skills in concert with disciplinary-oriented scientific and technical knowledge are difficult to effect. Changes related to attitudes and skills are more difficult to define than disciplinary knowledge based materials and to identify in terms of measurable outcomes. Finally, changes related to attitudes and skills are most effectively learned as integral parts of disciplinary subject matter; thus, integration is required and an overall curriculum design and holistic approach to delivery is required (Wormley, 2004).

Universities and institutions have to reassess the adequacy of their existing curricula in fulfilling the needs arising from globalization (Cheah, Chen, and Ting, 2005), while Craig (2010) notes that engineering programs that do nothing to address the challenges of globalization will soon be irrelevant. As a result, Grandin and Hirleman (2009) advocate integrating global education into the engineering curriculum to achieve maximum impact on addressing societal needs. One
manner to facilitate such integration is widespread industry involvement in preparing global engineers.

Industry Involvement in Preparing Global Engineers

Beckman et al. (1997) notes that sometimes there is a gap between what industry needs and what universities offer. This is corroborated by Buonopane (1997), who advocates that engineering educators truly listen to the needs of industry. Jones (2003) suggests we need to question if today’s educational systems are appropriately realistic for an increasingly global economy, asking if our curricula meet the current needs of employers, to what extent employers should influence the nature of the engineering curriculum, and if employers a clear, stable, and sustainable vision of how this is to be is to be realized. Meantime, Arlett et al. (2010) describe the development of “experience-led degrees” that aim to equip students with the employability skills needed by industry. The authors explain that the term “experience-led engineering degree” means components of an engineering degree that develop industry-related skills and which may also include industry interaction.

Feedback from graduates and industry partners can help provide guidance to improving the preparation and ultimate performance of globally-oriented engineering students. May and Strong (2011) report that some employers find engineering graduates to be weak in the field of engineering design, innovation, communication, and associated professional skills. Martin et al. (2005) report on who well engineering graduates perceive their preparedness for work in industry. Respondents perceived their strengths to be their technical background, problem solving skills, formal communication skills and lifelong learning abilities. The following areas of weakness were also identified: work in multidisciplinary teams, leadership, practical preparation, and management skills.

Finally, Genheimer et al. (2009) outline effective strategies for involving industry colleagues in helping to influence curriculum, engage with students, assist with accreditation, and provide resources for engineering education. Such is the goal of the Attributes of a Global Engineer Project, which reflects significant input and support from the Corporate Member Council (CMC) of the American Society for Engineering Education.

Initial Attribute Development and Refinement

The process of initially developing the Attributes of a Global Engineer began in 2008, led by the International Engineering Education Special Interest Group (SIG), and involved CMC members developing a list of competencies derived from representative job descriptions, literature reviews, and other reports. This initial list was consolidated through a series of SIG meetings and events throughout 2008 and 2009; thus, here are the first set of broad categories of attributes that emerged through this process:

- Engineering Science Fundamentals
  - Mathematics (including statistics)
  - Physical and Life Sciences
  - Political and Socio-economic Sciences
Information Technology - Digital Competency

Engineering
- Understanding of Design and Product Processes
- Understanding of Product Life Cycle Development
- Effective Teamwork/Common Goals
- Possess a Multi-Disciplinary, Systems Perspective
- Maintain Focus with Multiple Project Assignments

Context in which Engineering is practiced
- Economics/Finances of Projects
- Basic Supplier Management Principles
- Customer and Societal Emotions and Needs
- Cultures, Languages, and Business Norms
- Societal, Economic, and Environmental Impacts of Engineering Decisions
- An International/Global Perspective

Communication
- Written (Memos, reports, email, letters, etc.)
- Verbal (Technical & non-technical presentations plus an effective “elevator” speech)
- Foreign Language (Technically fluent in at least two languages acknowledging English is considered a key global language)
- Graphic (Design drawings, charts & graphs, presentation, and basic brochure design)
- Digital Competency
- Competent at Internet Collaboration and Communication Tools (Web-based meeting tools, team rooms, teleconferencing; file sharing, E-mail, etc.)
- Listening

Teamwork
- Active and Effective Participation in Team Efforts
- A Willingness to Respect the Opinions of Others and Support Team Decisions

Leadership
- An Acceptable Personal Image and a Positive Personal Attitude
- Treating People with Fairness, Trust, and Respect
- Respect for Diversity
- Courtesy and Respect
- An Eagerness to Help Others

Flexibility
- Self-Confidence to Adapt to Rapid/Continuous/Major Change
- Thinking Both Critically and Creatively - Independently and Cooperatively

Curiosity and Desire to Learn - For Life (Show initiative, Inquire & Learn)
- Seeking Advice and Forming Daily Questions to Discover New Insights.
- Commitment to Quality, Timeliness, and Continuous Improvement
- Understanding Basic Project and Risk Management and Continuous Improvement Concepts (like LEAN+)

Ethical Standards and Professionalism
- Operate in Accordance With Acceptable Business, Societal, and Professional Norms
- Maintain the Highest Level of Integrity, Ethical Behavior, and Professional Competence
- Understand and Applies Good Personal Judgment
At the ASEE Annual Conference in 2010, SIG stakeholders attempted to translate the attributes into specific competencies that could be identified by levels of importance and proficiency at certain intervals of an individual’s education and professional development. The initial list totaled forty-eight; however, through in-person meetings at the Conference, and through bi-weekly telephone conference calls and other electronic communication, the list was ultimately synthesized and consolidated. After further review and validation from CMC members, a total of twenty attributes of a global engineer emerged. These are:

1. Demonstrates an understanding of engineering, science, and mathematics fundamentals
2. Demonstrates an understanding of political, social, and economic perspectives
3. Demonstrates an understanding of information technology, digital competency, and information literacy
4. Demonstrates an understanding of stages/phases of product lifecycle (design, prototyping, testing, production, distribution channels, supplier management, etc.)
5. Demonstrates an understanding of project planning, management, and the impacts of projects on various stakeholder groups (project team members, project sponsor, project client, end-users, etc.)
6. Demonstrates an understanding of the ethical and business norms and applies norms effectively in a given context (organization, industry, country, etc.)
7. Communicates effectively in a variety of different ways, methods, and media (written, verbal/oral, graphic, listening, electronically, etc.)
8. Communicates effectively to both technical and non-technical audiences
9. Possesses an international/global perspective
10. Possesses fluency in at least two languages
11. Possesses the ability to think both critically and creatively
12. Possesses the ability to think both individually and cooperatively
13. Functions effectively on a team (understands team goals, contributes effectively to team work, supports team decisions, respects team members, etc.)
14. Maintains a positive self-image and possesses positive self-confidence
15. Maintains a high-level of professional competence
16. Embraces a commitment to quality principles/standards and continuous improvement
17. Embraces an interdisciplinary/multidisciplinary perspective
18. Applies personal and professional judgment in effectively making decisions and managing risks
19. Mentors or helps others accomplish goals/tasks
20. Shows initiative and demonstrates a willingness to learn

Survey Research on the Attributes of a Global Engineer

After completing a stakeholder-driven process to develop the attributes of a global engineer, SIG members sought to validate the list of attributes with stakeholders beyond the CMC. Given the global dimensions and emphasis of the attributes, SIG members were desirous of a mechanism to receive widespread feedback from a truly global audience of engineering-oriented stakeholders.

Survey Development and Launch
The CMC partnered with the International Federation of Engineering Education Societies (IFEES) to accomplish the goal of widespread global stakeholder input and validation. IFEES consists of nearly 50 member organizations, representing engineering education associations and corporations from around the globe. Dr. Hans Hoyer, who serves Secretary General of IFEES, facilitated connections between the SIG leading the attributes of a global engineer project and IFEES stakeholders around the globe. This purpose was two-fold: (1) to garner assistance in translating the survey into multiple languages (including validation of the survey once translated); and (2) to secure assistance in marketing the survey opportunity to IFEES stakeholders worldwide.

From July-September 2010, the survey was translated from English to the following languages: Chinese (Simplified and Traditional), French, German, Italian, Japanese, Korean, Polish, Portuguese, Russian, Spanish and Turkish. Translators also assisted in validating the survey with a small representative audience of likely survey responses. This was done to ensure that the intent behind attribute meanings was preserved across all translations. Translators were asked to make appropriate substitutions to words or phrases in the translated context to accomplish this goal. Using SurveyMonkey as the data collection platform, the survey was launched in October 2010; a work-in-progress paper was presented at ASEE’s 2011 Conference in Vancouver; additional responses were received by and the survey was closed for additional responses in September 2011.

There are several strengths and limitations to the sampling procedures involved in this survey’s development and deployment. Strengths include: the prolonged stakeholder-driven processes in which to conceptualize, collect, synthesize, summarize, and refine the list of 20 attributes of a global engineer; the involvement of both ASEE and IFEES members in providing input into and validating the initial survey; and the translation of the survey into multiple languages and the simultaneous global launch of the survey, including a coordinated communication plan inviting widespread participation. Limitations include: the inability to accurately define a true sampling frame; the reliance on a vast network of international contacts through ASEE and IFEES to help promote the survey’s availability; the English language-centric number of responses, despite multiple translations of the survey into multiple languages; and the less-than-anticipated number of total responses. Against the backdrop of these strengths and limitations, the next section highlights survey findings.

Summary of Key Findings

The survey yielded 1,027 usable case respondents reflecting the following demographic profile:

- 70% English; 30% non-English; responses were received from all languages except French
- 80% Male; 20% Female
- 50% between ages of 40-60; balance over other age ranges
- 46% Academicians; 40% Practitioners; 10% Students; balance preferred not to answer
- Aerospace (17%); Computer Science (13%); and Electrical/Computer (13%) are largest Engineering Discipline response categories
- 64% reported having graduate-level Engineering degree
Data analyses revealed the following attributes were most important and proficient overall:

1. Communicates effectively in a variety of different ways, methods, and media
2. Possesses the ability to think both critically and creatively
3. Shows initiative and demonstrates a willingness to learn
4. Functions effectively on a team
5. Possesses the ability to think both individually and cooperatively
6. Demonstrates an understanding of engineering, science, and mathematics fundamentals
7. Demonstrates an understanding of information technology, digital competency, and information literacy
8. Maintains a positive self-image and possesses positive self-confidence

When analyzing above attributes at each stage of an engineer’s development (upon completion of high school/secondary school; university; early-career professional), the importance and proficiency levels of each attribute varied, as follows:

The most important/proficient attributes for the secondary school graduate are:

1. Demonstrates an understanding of engineering, science, and mathematics fundamentals
2. Maintains a positive self-image and possesses positive self-confidence

For individuals at this stage, the need to have sound preparation in the disciplinary fundamentals is needed for successful transition to and success in university-level engineering education programs. Furthermore, student retention and success in most first-year university engineering curricula requires resiliency and the positive self-image/self-confidence.

The most important/proficient attributes for the university/post-secondary graduate are:

1. Demonstrates an understanding of engineering, science, and mathematics fundamentals
2. Demonstrates an understanding of information technology, digital competency, and information literacy.

For individuals at this stage, the need to have master of the disciplinary fundamentals upon departure from university-level engineering programs is most important. Furthermore, the ability to be proficient in and up-to-date with the tools and technology of the field are also needed.

The most important/proficient attributes for the early-career engineering professional are:

1. Functions effectively on a team
2. Possesses the ability to think both individually and cooperatively

For individuals at this stage, the need to work as part of an engineering-oriented team are most important, as is the ability to make both individual and collective contributions to engineering-oriented work.
After analyzing, summarizing, and disseminating results from the survey, SIG members felt it was necessary to conduct focus groups and workshops related to the attributes. The next section highlights the process and findings from those endeavors.

In order to garner additional input into the Attributes of a Global Engineer, a series of focus groups and workshops were conducted in several venues. From 2012-2015, events were held at engineering-related conferences, symposia, and workshops in these locations:

- San Antonio, Texas (June 2012)
- Turku, Finland (August 2012)
- Phoenix, Arizona (February 2013)
- Atlanta, Georgia (June 2013)
- Brussels, Belgium (September 2013)
- Cartagena, Colombia (September 2013)
- San Antonio, Texas (October 2013)
- Lexington, Kentucky (November 2013)
- Indianapolis, Indiana (June 2014)
- Palo Alto, California (June 2014)
- Kanazawa, Japan (July 2014)
- Birmingham, United Kingdom (September 2014)
- Madrid, Spain (October 2014)
- Dubai, United Arab Emirates (December 2014)
- Bangalore, India (January 2015)

In all but one event, the principal attendees were university-level engineering educators or industry partners. The October 2013, San Antonio, Texas, event provided an opportunity for K-12 and community/technical college stakeholders to have input into the Project. Each event was structured as both a focus group (to seek stakeholder input) and a workshop (to permit the dissemination of findings and encourage integration of attributes into the engineering curriculum).

During the focus group portion, highlights from the survey findings were shared and discussed, and participants had an opportunity to provide reactions or contribute additional information related to the attributes. A summary of the attributes the collective stakeholders from all events felt were needed for engineers to be successful in the global context included the following:

- Cultural sensitivity
- Tolerance to other people and perspectives
- Open-minded and ability to adapt
- Ability to behave ethically across cultures
- Social responsibility
- Research and analytical thinking
- Problem-solving and improvement capabilities
- Entrepreneurship
Stakeholders at each event were also queried as to the best uses of the attributes, which they identified as:

- Teaching and learning processes and student preparation
- Business/industry involvement as vocal advocate for attributes
- Linkages to other initiatives

Finally, while focus group and workshop participants uniformly expressed appreciation for the Attributes of a Global Engineer Project, there was widespread agreement that a framework of twenty attributes seemed daunting to remember, explain, or champion. Thus, stakeholders provided useful guidance on helping SIG members develop a revised framework.

**Revised Framework for the Attributes of a Global Engineer**

To facilitate greater utility of explaining the purpose of the Attributes of a Global Engineer, and to encourage their integration into the engineering curriculum, SIG members have revised the framework based on feedback from focus group and workshop participants. The new framework retains the twenty attributes, yet organizes them more effectively around five broad categories needed for global engineering effectiveness: Technical; Professional; Personal; Interpersonal; and Cross-cultural. Descriptions of each category and corresponding attributes are listed below:

**Technical:** Engineering-related knowledge, skills, and abilities needed for success

- Demonstrates an understanding of engineering, science, and mathematics fundamentals
- Demonstrates an understanding of information technology, digital competency, and information literacy
- Demonstrates an understanding of stages/phases of product lifecycle (design, prototyping, testing, production, distribution channels, supplier management, etc.)
- Demonstrates an understanding of project planning, management, and the impacts of projects on various stakeholder groups (project team members, project sponsor, project client, end-users, etc.)

**Professional:** Workplace related competencies for global performance

- Communicates effectively in a variety of different ways, methods, and media (written, verbal/oral, graphic, listening, electronically, etc.)
- Communicates effectively to both technical and non-technical audiences
- Maintains a high-level of professional competence
- Embraces a commitment to quality principles/standards and continuous improvement
- Applies personal and professional judgment in effectively making decisions and managing risks
**Personal:** Individual characteristics needed for global flexibility

- Possesses the ability to think both critically and creatively
- Possesses the ability to think both individually and cooperatively
- Maintains a positive self-image and possesses positive self-confidence
- Shows initiative and demonstrates a willingness to learn

**Interpersonal:** Skills and perspectives to work on interdependent global teams

- Functions effectively on a team (understands team goals, contributes effectively to team work, supports team decisions, respects team members, etc.)
- Mentors or helps others accomplish goals/tasks

**Cross-cultural:** Society and cultural understanding to embrace diverse viewpoints

- Demonstrates an understanding of political, social, and economic perspectives
- Demonstrates an understanding of the ethical and business norms and applies norms effectively in a given context (organization, industry, country, etc.)
- Possesses an international/global perspective
- Possesses fluency in at least two languages
- Embraces an interdisciplinary/multidisciplinary perspective

Future dissemination concerning the Attributes of a Global Engineer Project will use the revised framework as the means of organizing and communicating the attributes.

**Conclusion**

The Attributes of a Global Engineer Project has enjoyed several strengths, challenges, and opportunities. *Strengths* include corporate voices reflected in origin and concept development; mixed method approach for attribute development and refinement; and prolonged engagement with global stakeholders. *Challenges* include the large number of attributes identified; competing and co-existing “outcomes” frameworks exist; and engineering curricular tightness, which makes additive educational work impractical. *Opportunities* include the ability to offer corporate perspectives on related initiatives; integrating the attributes with curricular and other efforts possible; and adaptation to local contexts, versus superimposing the attributes on others. The SIG members look forward to continued evolution, dissemination, and improvement of the Attributes of a Global Engineer Project, and to seeing this effort scale and sustain over time.
Bibliography


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