AC 2012-4233: ATTRIBUTES OF A GLOBAL ENGINEER: FIELD-INFORMED PERSPECTIVES, RECOMMENDATIONS, AND IMPLICATIONS

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Lynn Brown is the Boeing Corporate Program Manager for University Relations International and the Co-chair for the ASEE Corporate Members Council Special Interest Group for International Engineering Education. Brown was named as University Relations Program Manager in 2004. In this position, she has oversight of various programs and projects for international and domestic higher education engagements. This includes such things as: developing corporate policy, procedures and guidelines for Boeing international university relationships; providing recommendations to the Higher Education Integration Board and executive sponsors for country and university relations global expansion for Boeing's strategic workforce; leading a global network of Boeing Country/Regional Focals for alignment and implementation of Boeing's University Relations Strategies; and managing the company's domestic university relations portfolio of more than 160 higher education institutions. Annually, University Relations provides more than $6.5 million of charitable and business contributions for international and domestic higher education engagements. Prior to this assignment, Brown managed the Educational Partnerships group in Boeing's training organization. In this position, she was responsible for conducting integrated and sustained partnerships with schools, colleges, and universities to communicate skills required by the manufacturing industry. During this time, she served as Chairperson for the National Employer Council for Workforce Preparation for three years; Chairperson of the Board for the Manufacturing Technology Advisory Group for seven years; Chairperson of three National Science Foundation Review Committees for manufacturing and engineering related grants; and conference committee member of the National Career Pathways Network; as well as serving on a number of state and local boards and skills standards committees. Brown attended the University of Texas, Austin, for her Ph.D. work in higher educational administration, Northern Arizona University for her M.A. in curriculum and assessment, and Arizona State University for her B.A. in secondary education - communications.

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As a member of ASEE since 1994, Alan Jacobs has served the society in numerous leadership roles. He founded the ASEE Corporate Member Council (CMC) Special Interest Group (SIG) on International Engineering Education and is currently Co-chair of that SIG. Jacobs is presently in his second term on both the ASEE CMC Executive Committee and the ASEE Projects Board and is the Secretary/Treasurer of the ASEE CMC. He also serves on the ASEE Journal of Engineering Education Advisory Board and was a contributor to ASEE's "Advancing the Scholarship of Engineering Education: A Year of Dialogue." Jacobs was previously a member of the ASEE International Strategic Planning Task Force, the International Federation of Engineering Education Societies (IFEES) Executive Committee, and General Motors' Partners for the Advancement of Collaborative Engineering Education Core Team. Jacobs has spent his professional career committed to helping colleges and universities gain enhanced access to teaching tools and to advancing the learning opportunities available to their students. By managing and growing innovative education initiatives for technology companies, Jacobs has provided programs and resources to assist institutions of higher learning in preparing their students for academic and career success. Jacobs has

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worked in key positions for such well-known global market leaders as Autodesk, Avid Technology, and Addison-Wesley Publishing. During his career he has held positions as, among others, Director - Worldwide Education, Executive Editor, Senior Product Manager, and Senior Marketing Manager. Presently, he is self-employed as an Education Market Business Development Consultant, most recently serving as an interim executive hired as Director, U.S. Academic Relations to reverse Quanser's declining U.S. educational revenues. Jacobs holds a master's of education and a master's of regional planning from the University of Massachusetts and has had special training as a Practitioner of neuro-linguistic programming and in mediation. Jacobs is a third-degree black belt in Tang Soo Do. He lives in Falmouth, Mass., with his wife and son.

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Hans J. Hoyer is Director for International Programs, ASEE; Secretary General of the International Federation of Engineering Education Societies (IFEES); and Executive Secretary of the Global Engineering Deans Council (GEDC). Prior to 2006, Hoyer was CEO of World Links, a spin-off of the World Bank. In this capacity, he worked globally on issues related to secondary education, teachers' education, and on-ine collaborative learning focusing on science and social studies among high school students across the globe. Hoyer has been a Visiting Scholar at the Center for International Studies at MIT, a Fellow at Harvard's School of Education and Visitor at the Kennedy School of Government. He was Dean of the graduate program at the School for International Training, World Learning, and Executive Director of the Executive Training program for global governmental and NGO leaders in Brattleboro, Vt. Prior to this, he taught cultural anthropology and Latin American Studies at George Mason University in Fairfax, Va., and Montgomery College, Takoma Park, Md. He earned his Ph.D. at American University in Washington, D.C., and was a postdoctoral Fellow at the Organization of American States, carrying out research in the Rio de la Plata region of South America. He started his career as a Peace Corps Volunteer and high school teacher in Linares and Talca, Chile, and has lived in more than 20 countries including Chile, Peru, Brazil, Ecuador, Paraguay, Argentina, Mexico, South Asia, Europe, and Sub-Saharan Africa. Over his extensive career, he has visited more than 125 countries and is fluent in four languages and conversant in an additional five languages. Hoyer has led several international development programs, including CARE, Plan International, and Heifer International. In these latter roles, he held executive leadership positions such as Senior Vice-President/Chief Operating Officer and Regional Executive and was responsible, among others, for raising large financial resources from a multitude of donors including U.S. government agencies, the World Bank, IAB, and several foundations, corporations, and private donors. He also represented the largest U.S. farming membership association as a spokesperson at the European Union and European Parliament in Brussels and also represented them in Mexico and Central America. He has served on the Board of Directors with Nelson Mandela of El Taller, a global civil society network headquartered in Tunisia, as well as on several social-action community groups. He was also on the staff of the Inter American Foundation, created by the U.S. Congress to support socio-economic development throughout Latin America/Caribbean. He was on the advisory board of Hewlett Packard's e-Inclusion Global Advisory Board related to their work in South Africa and is currently on the Advisory Board of the Engineering for the Americas (EftA) initiative which is under the umbrella of the OAS. He has written on a broad range of subjects related to international development, politics, health, education, and engineering education. Born in Berlin, Germany, he immigrated to the U.S. as a teenager. His wife is Canadian and he has four children who were born in the U.S., Brazil, Mexico, and Belgium. His oldest son is a physician at Johns Hopkins University Hospital, and his oldest daughter, an occupational therapist, is the co-owner of an occupational/physical therapy clinic. He has two small children ages 12 and 10 and is therefore deeply interested in the issues related to science and engineering for the young. His wife is Global Director for PR in Johnson Control (JCI).

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Attributes of a Global Engineer: Field-Informed Perspectives, Recommendations, and Implications

Abstract

What knowledge, skills, abilities, and characteristics are needed by engineering professionals living and working in an increasingly global context? At what stage of an engineer's professional development are these attributes acquired and applied? In what ways do academicians, employers, policymakers, and others play a role in equipping engineering students and practitioners with such attributes? And to what extent are there similarities and differences in the nature of expected attributes based on one's background or location?

For the past three years, the ASEE Corporate Member Council's Special Interest Group for International Engineering Education developed, presented, and vetted with its stakeholders a series of attributes representing the desired competencies and characteristics needed by engineers in order to effectively live and work in a global context. An online survey was launched to validate the performance and proficiency levels of each attribute, including the stages at which attributes were essential to the preparation, performance, and employability of global engineers. Educators, employers, students, and professional engineers throughout the global engineering community were invited to participate in the survey. To promote input and obtain feedback from the largest possible global engineering audience, ASEE collaborated with the International Federation of Engineering Education Societies (IFEES) to make the survey available in Chinese, English, French, German, Italian, Japanese, Korean, Polish, Portuguese, Russian, Spanish and Turkish.

This paper describes the stakeholder-driven process to identify and define attributes of a global engineer; survey development and sampling procedures; summary of key findings-to-date; preliminary interpretations; and brief discussion and next steps.

Stakeholder-drive Process to Identify and Define Attributes of a Global Engineer

The ASEE Board of Directors established the ASEE Corporate Member Council 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

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 Survey Project.

The Attributes of a Global Engineer Survey 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.

The process began in early-2008, led by the International Engineering Education 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 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 48; 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 20 competencies associated with the 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 Development and Sampling Procedures

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. First, however, certain definitions were developed, as noted below:

Definition of Attributes:

Attributes: the desired competencies and characteristics needed by engineers in order to effectively live and work in a global context.

Definition of Role Levels:

Upon Graduation from a Secondary/High-School: graduation from a secondary/high-school and entering a tertiary/college/university to pursue an engineering program-of-study.

Upon Graduation from a Tertiary/College/University: graduation from a tertiary/college/university engineering program-of-study.

Early-Career Engineering Professional: employment in an engineering role during the 5 years immediately following graduation from a tertiary/college/university.

Definition of Importance Levels:

Extremely important: the knowledge, skills, abilities, and perspectives associated with this attribute are essential to successful performance outcomes of this role.

Important: the knowledge, skills, abilities, and perspectives associated with this attribute are generally needed for satisfactory performance outcomes of this role.

Slightly important: the knowledge, skill, abilities, and perspectives associated with this attribute are minimally needed for performance outcomes of this role.

Not important: the knowledge, skills, abilities, and perspectives associated with this attribute are not needed for performance outcomes of this role.

Definition of Proficiency Levels:

Advanced: specialized knowledge and complex functioning for this attribute have been acquired.

Intermediate: an increasing progression and familiarity beyond the fundamental or basic principles for this attribute have been acquired.

Basic: fundamental or basic principles for this attribute have been acquired.

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 as ASEE's Director of International Programs and Strategy and also as 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; for more details, please visit: http://www.ifees.net/activities/ASEECMCSIG-IFEES.cfm. For the purpose of preparing this paper, data from all surveys was downloaded and summarized on December 15, 2011; a full report to ASEE's CMC and IFEES will be produced in the spring of 2012.

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-to-date, despite multiple translations of the survey into multiple languages; and
- The presently less-than-anticipated number of total responses-to-date.

Against the backdrop of these strengths and limitations, SIG members felt it was important to update the engineering education community on the survey's preliminary findings. Thus, the next section highlights findings-to-date, provides a brief discussion of the findings, and outlines next steps in this project.

Summary of Key Findings-to-Date

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

- 70% English; 30% non-English; responses 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

Top Attributes by Role, Importance, and Proficiency

Early-Career Professionals: Importance and Proficiency

Attributes by Importance	Attributes by Proficiency
1. Communicates effectively in a variety of different ways, methods, and media	1. Communicates effectively in a variety of different ways, methods, and media
2. Possesses the ability to think both critically and creatively	2. Shows initiative and demonstrates a willingness to learn
3. Shows initiative and demonstrates a willingness to learn	3. Possesses the ability to think both critically and creatively
4. Functions effectively on a team	4. Functions effectively on a team
5. Possesses the ability to think both individually and cooperatively	5. Possesses the ability to think both individually and cooperatively

Upon Graduation from College or University: Importance and Proficiency

Attributes by Importance	Attributes by Proficiency
1. Shows initiative and demonstrates a	1. Demonstrates an understanding of

willingness to learn 2. Demonstrates an understanding of engineering, science, and mathematics fundamentals 3. Communicates effectively in a variety of different ways, methods, and media 4. Possesses the ability to think both critically and creatively 5. Demonstrates an understanding of information technology, digital competency, and information literacy	engineering, science, and mathematics fundamentals 2. Shows initiative and demonstrates a willingness to learn 3. Communicates effectively in a variety of different ways, methods, and media 4. Demonstrates an understanding of information technology, digital competency, and information literacy 5. Possesses the ability to think both critically and creatively

Upon Graduation from High School: Importance and Proficiency

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

Significant Differences Based on Language-/Role-based Responses

For certain attributes, there are significant differences based on language or engineering role:

Possesses fluency in at least two languages

- Non-English respondent Practitioners feel this attribute is more important for Early-Career Professionals than do English respondent Practitioners
- Non-English respondents Practitioners feel this attribute is more important for University graduates than do English respondents Practitioners
- Non-English respondents Practitioners feel this attribute is more important for H.S. graduates than do English respondents Practitioners
- Non-English respondent Practitioners feel more proficiency is needed for this attribute by H.S. graduates than do English respondent Practitioners
- English respondents Students, however, feel more proficiency is needed for this attribute by H.S. graduates than do non-English respondent Students

Demonstrates an understanding of information technology, digital competency, and information literacy

- Non-English respondent Students rate this attribute as more important for Early-Career Professionals than do English respondent Students

Shows initiative and demonstrates a willingness to learn

- Non-English respondent Students rate this attribute as more important for Early-Career Professionals than do English respondent Students
- English respondent Academicians, however, rate this attribute as more important for Early-Career Professionals than do non-English respondent Academicians

Demonstrates an understanding of political, social, and economic perspectives

- English respondent Practitioners rate this attribute as more important for University graduates than do non-English respondent Practitioners
- Both non-English respondent Academicians and Students, however, rate this attribute as more important for University graduates than do English respondent Academicians and Students

Embraces an interdisciplinary/multidisciplinary perspective

- Non-English respondent Students expect higher proficiency from H.S. Graduates than English respondent Students

Shows initiative and demonstrates a willingness to learn

- Both non-English respondent Students and Practitioners expect higher proficiency from H.S. Graduates than English respondent Students and Practitioners

Embraces a commitment to quality principles/standards and continuous improvement

- Non-English respondent Practitioners expect higher proficiency from H.S. Graduates on this attribute than English respondent Practitioners

Preliminary Interpretations

- All attributes have been validated as being important for a global engineer; some attributes are more important than others and the proficiency-levels needed at different "stages" of a professional's development necessarily vary
- Considerable agreement across all languages on the "most important" and "most proficient" attributes needed (the top 5 attributes for each "stage"), with some variance between order of importance and proficiency
- The means for importance and proficiency of each attribute are lower for H.S. Graduates, increase for University graduates, and are the highest for Early-Career Professionals; thus, this results in a stair stepping effect for attributes at each stage
- There are statistically-significant language- and role-based differences for some of the attributes, although most of the differences are not in "top 5" attributes
- Most qualitative verbatim responses identify a nuanced or more specific discussion of "missing" attributes

Next Steps in the Project

Members of the Special Interest Group on International Education from ASEE's Corporate Member Council are actively engaged in interpreting, analyzing, and developing a report on the findings from the Attributes of a Global Engineer Project. A recent strategic planning session, held in late-2011, identified the following questions that will guide the next steps in the project:

- What are the challenges of integrating the attributes in the engineering curricula vs. adding them on through coursework, experiential learning, or co-curricular means?
- To what extent will students be able to enhance their awareness and understanding of the attributes?
- To what extent can faculty help students understand what that coursework will lead to the acquisition and development of the attributes?
- To what extent does sequencing impact the acquisition and development of global attributes?
- To what extent do variable curricular approaches impact when, how, and where attributes are developed?
- To what extent are cultures adapting and adopting U.S.-based practices?
- What are student perceptions of attributes and what is their comfort level with the acquisition of the attributes?
- Where is the place where the attributes are acquired in the curriculum?
- To what extent would there be a greater disparity of role-based perceptions of importance/proficiency for attributes if other languages were more prominently represented in the survey results?
- To what extent can the SIG leverage international colleagues from ASEE and IFEES to ensure additional validation of attributes by international audiences?
- In what ways can the attributes be mapped to existing work, such as Grand Challenges, ABET, Engineer of 2020, Project Kaleidoscope, and the National Survey of Student Engagement?

To help answer these and other questions, specific next steps in the project include:

- Analysis, interpretation, and dissemination of survey results via a project report (released in 2012)
- Development of outcome statements for each attributes, informed through the literature and best practices of CMC member organizations
- Validation of outcomes statement for attributes through focus group research held at ASEE's 2012 Annual Conference in San Antonio in June; at the International Conference on Engineering Education in Finland in August; and at the World Engineering Education Forum in Argentina in October
- Pursuit of grant funding to develop and pilot test engineering-related curricular modules related to key attributes

Conclusion

The Attributes of a Global Engineer Project, initiated by the ASEE Corporate Member Council's Special Interest Group for International Engineering Education, has been active for the past

several years by: (1) identifying and clarifying the attributes needed for engineers to successfully live, work, and perform effectively in any setting around the world; (2) validating the attributes through a globally-launched survey that was translated into 13 languages and launched in conjunction with the International Federation of Engineering Education Societies; and (3) developing outcome statements that reflect the performance needed per outcome. Additional plans include: (1) conducting focus groups with representative stakeholders at global engineering education meetings to amplify and expand on outcome statements; (2) developing a project findings report; (3) publishing and presenting the results in peer-reviewed outlets; and (4) pursuing grant funding to help educators, employers, and policymakers understand and implement some of the implications of the project. Thus, while there is still much work to be accomplished in the Attributes of a Global Engineer Project, this paper provided a background on the framework and an update on the progress-to-date on an activity of significant importance to stakeholders in the engineering education international community.