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The Attributes of a Global Engineer: Purpose, Perspectives, and Progress

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Lynn G. Brown is the Corporate Higher Education and STEM International program manager for for The Boeing Company and the Chairperson of the ASEE Corporate Members Council Special Interest Group for International Engineering Education. Selected as Boeing's Corporate Higher Education program manager in 2004, Brown became the leader of various programs and projects for predominately domestic higher education engagements. Due to Boeing's desire for international expansion, the responsibility of growing Boeing's Higher Education International engagements was added to her preview. Brown develops corporate policy, procedures and guidelines for international university relationships for workforce needs, continuing education requirements, potential research projects, building the Boeing brand and reputation. She also establishes corporate infrastructure and leads a global network of Boeing executives for implementing Higher Education engagements for the company, and works across Boeing organizations to align higher education engagements and funding to the various Boeing Presidents' country Strategies. Annually, Boeing provides over $7.1 million dollars of charitable and business contributes for international and domestic higher education engagements through Higher Education and STEM. Prior to this assignment, Brown managed the Educational Partnerships group in Boeing's training organization. She was responsible for conducting integrated and sustained partnerships and internships with schools, colleges, and universities to communicate skills required by the manufacturing industry. During this time, she served as chairperson for the following: National Employer Council for Workforce Preparation for three years; Manufacturing Technology Advisory Group Board of Directors for seven years; and three National Science Foundation Review Committees for manufacturing and engineering-related NSF grants. Brown also served as a conference committee member of the National Career Pathways Network and serving on a number of state and local boards and skills standards committees. She has taught at the secondary, community college and university levels as well as been a research associate at IC2 Institute in Austin, Texas. Brown attended the University of Texas at 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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Patricia Fox is associate chair of the Department of Technology Leadership and Communication in the Purdue School of Engineering and Technology at IUPUI. Fox has previously served on the ASEE Board of Directors for three terms and has been involved with many ASEE groups including the Engineering Technology Council, Engineering Technology Division, Corporate Members Council, Student Division, and International Division. Fox teaches ethics, leadership and sustainability courses at IUPUI.

Ms. Catherine Didion, National Academy of Engineering

Catherine Didion is a senior program officer at the National Academy of Engineering (NAE). Her portfolio includes the Diversity of the Engineering Workforce program with a charge to provide staff leadership to the NAE's efforts to enhance the diversity of the engineering workforce at all levels including the diversity of those being prepared to enter the future workforce. Current projects include the Engineer Girl web site that is geared to middle school students with a focus on encouraging girls to consider engineering studies and careers and the Engineer Your Life web site for high school students. Didion is the principal investigator (PI) of a National Science Foundation (NSF) grant, The 2-Year to 4-Year Engineering and Engineering Technology Transfer Students Pilot Project, aiming to better understand the number of community college students enrolled in individual engineering programs as well as those who

have either completed an associates degree program or directly transferred to a baccalaureate programs. Didion was the project director of a $2.5 million dollar National Science Foundation grant to increase the number of women receiving baccalaureate degrees in engineering that was completed in 2012. In addition to her duties at NAE, Didion is the director of the Committee on Women in Science, Engineering, and Medicine. This is a standing committee with a mandate to work as a focal point on gender across the three National Academies. Didion served as executive director for the Association for Women in Science (AWIS) for fourteen years. During her tenure AWIS was awarded the U.S. Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring and she was the PI for seventeen government and foundation grants. Didion has presented testimony before the U.S. Congress and U.S. federal agencies. Didion has extensive experience on Capitol Hill including the U.S. Senate Commerce, Science, and Transportation Committee. Didion was named in 2012 one of ”100 Women Leaders in STEM.” Her honors include American Association for the Advancement of Science (AAAS) Fellow; AWIS Fellow; Drucker Foundation Fellow; Texaco Management Institute Fellow; Secretary of the US Air Force Inaugural Environmental Civic Leaders Tour; and Certificate of Commendation and Distinguished Service, Embassy of the United States of America.

Mr. Daniel R. Sayre, John Wiley & Sons, Inc.

An engineering publishing professional for more than 25 years, Sayre has been associate publisher for Engineering in Wiley's Global Education division since 2005. He previously served as VP-publisher of Island Press and prior to that held several editorial and marketing positions in Wiley's Professional and Trade Division. Sayre is a former director of the ASEE Corporate Members Council and a past president of Washington Book Publishers.

The Attributes of a Global Engineer Project:
Purpose, Perspectives, and Progress

Abstract

For the past three years, the American Society for Engineering Education (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. A global 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. This paper will describe the stakeholder-driven process to identify and define attributes of a global engineer, including survey development and sampling procedures; present a summary of key findings-to-date; discuss how attribute outcomes can be used to enhance engineering education globally; and highlight the recommendations and implications for a variety of stakeholders.

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 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	1. Communicates effectively in a variety of different ways, methods, and media 2. Shows initiative and demonstrates a willingness to learn 3. Possesses the ability to think both critically and creatively 4. Functions effectively on a team 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 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	1. Demonstrates an understanding of 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

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 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 2013)
- 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, funded by a CMC partner organization, held in the U.S., Latin America, Asia, Europe, and the Middle East
- 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.