Online Journal for Global Engineering Education

Volume 8 | Issue 1 Article 1

March 2014

Global Engineering Competency in Context: Situations and Behaviors

Brent K. Jesiek
Purdue University, bjesiek@purdue.edu

Qin Zhu
Purdue University, qinzhu@purdue.edu

Sang Eun Woo
Purdue University, sewoo@purdue.edu

Julia Thompson
Purdue University, thomps87@purdue.edu

Andrea Mazzurco
Purdue University, amazzurc@purdue.edu

Global Engineering Competency in Context: Situations and Behaviors

Cover Page Footnote

An earlier version of this paper appeared in the Proceedings of the 2013 ASEE International Forum, Atlanta, GA, June 22, 2013. All unmodified portions of this paper are republished with permission from the American Society for Engineering Education (ASEE), the original copyright holder. The authors gratefully acknowledge support for aspects of this work under National Science Foundation (NSF) grant EEC-1160455, “Global Engineering Competency: Definitions, Development Paths, and Situational Assessment.” We extend appreciation to affiliates of the Global Engineering Education Collaboratory (GEEC) for their extensive assistance with this project, and anonymous reviewers whose thoughtful feedback helped us improve the final draft.

The Online Journal for Global Engineering Education

Global Engineering Competency in Context: Situations and Behaviors

Brent K. Jesiek
Assistant Professor
School of Engineering Education
Purdue University

Qin Zhu
Graduate Research Assistant
School of Engineering Education
Purdue University

Sang Eun Woo
Assistant Professor
Department of Psychological Sciences
Purdue University

Julia Thompson
Ph.D. Candidate
School of Engineering Education
Purdue University

Andrea Mazzurco
Graduate Research Assistant
School of Engineering Education
Purdue University

ABSTRACT

Engineering graduates encounter worlds of professional practice that are increasingly global in character. This new reality poses challenges for engineering educators and employers, who are faced with the formidable task of preparing engineers to be more effective in diverse national and cultural contexts. In response, many commentators have proposed lists of attributes or competencies deemed important or even essential for global engineering work. However, such lists have tended to lack explicit grounding in empirical studies of engineering practice, including typical kinds of work situations and related behavioral requirements. As a step toward establishing a more robust definition and developmental theory of global engineering competency, this paper reports results from a wide-ranging literature review on engineering practice in global context. The findings are organized around three main contextual dimensions of global engineering competency: technical coordination; engineering cultures; and ethics, standards, and regulations. Particular efforts are made to relate our findings to prior discussions of what it means to be a globally competent engineer, while further illustrating each dimension by giving examples drawn from interviews with practicing engineers. The paper concludes with a review of ongoing and future work, including how our findings are inspiring creation of situational prompts and activities for both assessment and instructional uses.

INTRODUCTION

Whether working on multi-national project teams, navigating geographically dispersed supply chains, or engaging customers and clients abroad, engineering graduates encounter worlds of professional practice that are increasingly global in character. This new reality poses challenges for engineering educators and employers, who are faced with the formidable task of preparing engineers to be more effective in diverse national and cultural contexts. In response, more global learning opportunities are being made available to engineering students, as reflected in gradual yet steady increases in the number of global engineering programs and participating students.[1] Many companies also offer professional development opportunities to help their employees learn foreign languages and cultures, cultural etiquette, and global leadership skills. Nonetheless, there remain questions about what specific capabilities are most important for global engineers, and what types of training and work experiences best cultivate such capabilities.

One typical response to such questions involves developing lists of attributes or competencies deemed important or even essential for global engineering work. However, such lists have tended to lack explicit grounding in empirical studies of engineering practice. Even when such possible links are explored, scholars face a large and diffuse body of literature discussing the manifold challenges faced by engineers and other technical professionals when working globally. Those wishing to carry out their own original research on global engineering work face still more hurdles, including significant overhead costs related to data collection and analysis, and considerable variations in the nature of professional practice depending on the geographic locale, industry sector, job role, and firms being studied. In response to these challenges and in line with a broader "turn toward practice" in the engineering education and engineering studies fields[2-3], this paper proposes that additional research is sorely needed to investigate the types of work situations most frequently encountered by global engineers. These inquiries can in turn allow identification of context-appropriate behaviors that are required in such situations, along with specific attributes (knowledge, skills, attitudes, etc.) that inform or underlie such behaviors. Such research constitutes a key ingredient in efforts to enhance global engineering education.

As a step toward building a more satisfactory definition and developmental theory of global engineering competency, this paper reports results of a wide-ranging literature review focused on engineering in a global context. The analyzed literature includes articles, papers, and reports drawn primarily from the fields of engineering education, business and management, organizational psychology, and human resources. The primary inclusion criteria for creating this collection centers on identifying descriptions of situations that involve: 1) globally competent behaviors, 2) individuals from multiple national, regional, and/or ethnic cultures, and 3) technical tasks and/or problem solving. Particular emphasis is placed on case studies that provide detailed, practice-based accounts of global technical work, which allows for identification of specific types of work situations and context-appropriate behaviors. To further enrich our account, we draw example situations and reflections from interviews we conducted with practicing engineers.

The sections that follow begin with additional background for our study, including a discussion of related literature and reasons for looking at global engineering from new and different angles. We then turn to a brief overview of our current data collection and analysis efforts, followed by a discussion of findings organized around three main contextual dimensions of global engineering competency: technical coordination; engineering cultures; and ethics, standards, and regulations. We conclude with a discussion of ongoing and future work, with an emphasis on how our research is inspiring development of situational prompts and activities that can be used for both assessment and instruction. The intended audience for this paper includes engineering educators and representatives from industry who seek clarity regarding how global engineers may be selected, managed, and/or developed. Additionally, many of the cases and other materials discussed in this paper can potentially be used in existing training programs and courses.

BACKGROUND

Since at least the late 1940s and early 1950s, commentators have discussed what kinds of capabilities and training are important for engineers tasked with working across countries and cultures.[1] However, a variety of globalization trends, including intensified economic and technological competition among both countries and firms, have helped amplify these conversations in recent decades. The result has been a long string of commentaries and reports calling on educators to better prepare students in engineering and other STEM fields for the global realities they will likely face in their careers.[4-9]

These and many other reports and studies have also addressed questions about what specific kinds of competencies are important for the so-called "global engineer." For example, one forward-looking NRC report published in 1999 outlined a "global engineering skill set" with four main items: "(1) language and cultural skills, (2) teamwork and group dynamics skills, (3) knowledge of the business and engineering cultures of counterpart countries, and (4) knowledge of international variations in engineering education and practice."[10] Many other authors and groups have since created or compiled their own partially unique lists of competencies, and other efforts of this type are ongoing.[11-24] Accreditation guidelines and curriculum reports are still other important sources of evidence regarding the global dimensions of engineering practice.[25-27]

Nonetheless, this large body of literature raises two kinds of concerns. The first is largely methodological given considerable variability in how different definitions of global competency have been developed. More specific issues include a tendency to generate lists and frameworks based on relatively weak sources of empirical data, including prior literature (which itself often lacks empirical grounding), the experiences of the authors themselves, and/or pre-existing learning outcomes from relevant courses or programs. In other cases, the stakeholders consulted to help generate such lists are not adequately characterized, making it difficult to evaluate their qualifications and expertise. Many of the studies cited above suffer from such limitations.

A second kind of concern centers on the insufficient theoretical delineation and integration around the definitions themselves. Most notably, there remains a lack of clarity regarding how specific competencies are defined, much less what they mean in practice. The extant literature offers many dozens of different attributes and capabilities, yet these are often difficult to compare and contrast given considerable differences in terminology, theoretical foundations, and intended applications. Related concerns include a lack of grounding in relevant developmental frameworks (e.g., Bloom's Taxonomy), and little discussion of how certain attributes might be developed through specific kinds of learning experiences. In short, the current literature suggests considerable opportunities for building more robust theoretical and empirical foundations.

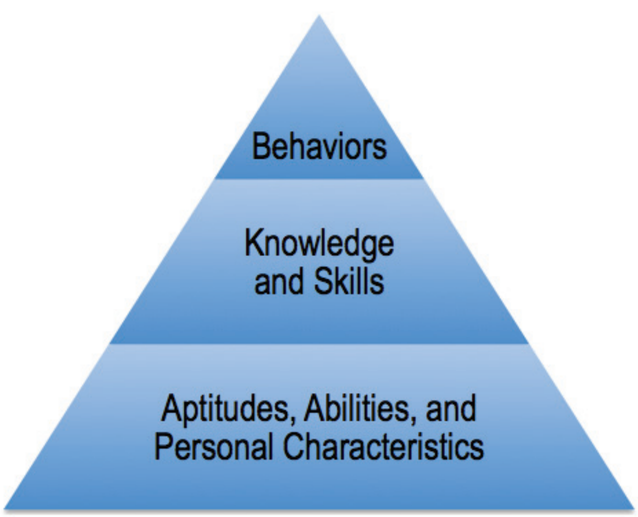

Figure 1. Competency Pyramid, adapted from Lucia and Lepsinger[29]

The work presented here responds to these challenges in two ways. First, we take theoretical inspiration from more generalized models of individual competency. The type of competency pyramid presented in Lucia and Lepsinger's influential work and shown in Figure 1, for instance, posits a hierarchical relationship that begins with a base representing an individual's innate abilities and personal characteristics, above which is a level consisting of acquired knowledge and skills, and finally culminating at the top of the pyramid with behaviors.[29] Such a model makes explicit how various innate and acquired attributes undergird an individual's behavioral responses in real-world situations. Further, this approach suggests that an important first step in understanding competency involves beginning at the relatively more opaque yet complex top of the pyramid, namely by probing the kinds of work situations and related behavioral requirements typically faced by individuals in certain domains of activity (e.g., global engineering practice).

Second, it is important to carefully delimit the scope of such an inquiry to make it more manageable. We do so by considering the competencies of an engineer using three partially distinct categories, as outlined in previous work.[30] The first centers on foundational technical and professional attributes that are not explicitly global in nature, but are frequently viewed as important for most any practicing engineer, including engineering problem solving and design skills, communication and teamwork capabilities, etc. A second major category includes a variety of attributes that are viewed as important for most any global professional, such as foreign language proficiency, intercultural competence, a "global mindset," and appropriate cultural and historical knowledge. We distinguish and bracket these two categories because there are already large and growing bodies of literature concerned with defining, developing, and assessing these types of competencies.

Our research is mainly focused on a third category that we call *global engineering competency,* defined as those *capabilities and job requirements that are uniquely or especially relevant for effective engineering practice in global context*.[30] Marking this as a distinct category of interest emphasizes that expectations for effective in-role behavior (i.e., job performance) are often locally contextualized (e.g., multi-cultural differences between countries or even companies) and field-specific (e.g., engineering vs. medicine).[31] For example, expectations about what it means to be a good team member or leader may change when looking at *technical teams* as compared to other kinds of teams, and may change yet again when looking at *cross-national/cultural* technical teams.

Nonetheless, there remain methodological questions about how one might identify and validate what counts as "global engineering competency." We address this challenge by setting aside the question of what underlying attributes are most important for global engineers, and instead focus on how experts actually *experience* global engineering practice.

STUDY DESIGN

Our study design begins by asking: What types of work situations do global engineers typically encounter, and what kinds of context-appropriate behaviors are required in these situations? At least two major sources of empirical data are potentially relevant for such an inquiry. As described in more detail below, primary data can be generated through direct interaction with experts – including through surveys, interviews, and/or focus groups – to identify prevalent work situations and related behavioral expectations. However, this paper is mainly focused on more readily accessible secondary sources of data, namely pre-existing case studies and other rich descriptions of global engineering practice. To scope our data collection efforts, we specifically seek out descriptions of critical incidents, case studies, and other kinds of situations that involve: 1) globally competent behaviors, 2) individuals from multiple national, regional, and/or ethnic cultures, and 3) technical tasks and/or problem solving.

Our ongoing search for relevant literature has been wide-ranging, but with a particular focus on publications from engineering and other technical fields, business and management, and cross-cultural studies. To date we have collected more than 50 relevant case studies from more nearly twenty different sources, including books, case study collections, and journal articles. The majority of the cases are based on actual, real-world situations, while others are hypothetical.

The research team has also conducted one-on-one and group (2-5 participant) interviews with 25 subjects. Most of these individuals hold one or more engineering degrees, and all have previous or current job roles involving global technical work, typically in large corporations. The data collection procedure involved first sensitizing interviewees to the domain of interest through discussion of a relevant global scenario prompt, presented as Figure 1 in the final section of this paper. The rest of the conversation utilized a critical incident approach to elicit stories of global engineering practice from participants.[34] The interviewer's role was largely limited to probing for details and helping respondents understand what kinds of stories were most relevant. All data was collected following appropriate procedures for interacting with human subjects, approved under Purdue IRB protocol no. 1112011599.

Our data analysis efforts involve development and application of a common coding framework for all of the cases and situations drawn from the literature and elicited from our research subjects. The categories and codes have been refined iteratively using both inductive and deductive approaches, allowing us to leverage our prior knowledge of the domain of interest as well as our growing familiarity with the collected data. The categories include:

- **National Cultures Involved:** Including host location and culture, and guest culture(s).
- **Situation-Motivation:** The main reason or motivation for the situation or case, such as expatriate assignment, greenfield plant start-up, cross-national collaborative project, etc.
- **Situation-Cultural Dimensions:** Relevant cultural dimensions such as power distance, individualism vs. collectivism, levels of nepotism, low vs. high context cultures, etc.
- **Situation-Other Dimensions:** Other salient dimensions evident in the case, including those related to global engineering competency (e.g., engineering cultures, ethics, etc.).
- **Personal Attributes:** Particular attributes or competencies explicitly mentioned as relevant or important for the case or situation described.

This paper reports on three specific contextual dimensions of global engineering competency identified through our wide-ranging review of literature, and further illustrated using examples drawn from our interview data. We particularly emphasize how these dimensions are reflected in the extant case literature, while also triangulating our findings with prior discussions of what it means to be a globally competent engineer. It should be emphasized that this phase of the study allows us to discuss what kinds of situations and behaviors appear most often in the data we have analyzed, while allowing us to map these findings to some of the capabilities described in previously published lists of attributes. Future research will involve further efforts to clarify what specific foundational attributes that are most salient for these situations and behaviors. We also discuss below how our results are being leveraged to both write questions for a new assessment instrument and create novel instructional materials such as multimedia case study vignettes.

FINDINGS

Technical Coordination

The broadest category of situations and behaviors evident in our data set involve what Trevelyan calls "technical coordination," or "working with and influencing other people so they conscientiously perform some necessary work in accordance with a mutually agreed schedule."[35] This is perhaps not surprising given growing evidence that technical coordination is often the most prominent type of work performed by engineers.[35-36] It usually involves informal rather than formal management tasks, and per Trevelyan may include activities such as: cooperating and coordinating with others both within and beyond the organization; supervising, monitoring, and reporting work progress; negotiating points of view; delegating work; team building and leading; networking; and developing policies and procedures. In the industrial-organizational psychology, business, and management fields, such activities are usually broadly classified as managerial or leadership tasks.[37-38]

Wading into the literature, we find that most of the cases presented by Acosta et al. in their *Global Engineering* text describe examples of technical coordination in cross-national/cultural context, including situations that involve working with others to design parts or tooling, diagnose and address problems, and implement new procedures or programs.[39] Common underlying motivations for these situations include quality control, inventory control, supply chain and logistics, worker productivity, and expansion/relocation issues. To interpret the cultural dynamics of these situations, the authors utilize Hofstede's cultural dimensions.[40] Many of the case studies and vignettes presented in Laroche's *Managing Cultural Diversity in Technical Professions* also involve technical coordination in the midst of cultural diversity, including in relation to supply chain issues, dealing with difficult customers and clients, working with non-technical managers, and grappling with context-dependent styles of delegating, overseeing, and executing technical work.[41] A Harvard Business Review case study by Yemen, on the other hand, examines Cisco Systems, Inc.'s move into China, focusing on both informal and formal management and leadership challenges in the context of a high-tech, multi-national firm.[42] Storti's collection of hypothetical cross-cultural dialogues also features some relevant examples, including one on the interaction of technical expertise and formal management hierarchies in China, and others involving quality control and engineering design situations in Latin America.[43]

Yet to what extent are facets of cross-cultural technical coordination reflected in the competency definitions referenced above? While not explicitly described, professional capabilities in related areas such as communication, leadership, teamwork, and project management are sometimes mentioned.[22] Other writers are more explicit about the cross-cultural dimensions of such attributes, as reflected in Mohtar and Dare's assertion that global engineers be able to "adapt to cultural norms in the professional arena and act appropriately," "communicate professionally in a culturally-appropriate manner," and "contribute to a culturally-diverse team."[24] Ball et al. mention a number of similar attributes, with particular emphasis on multicultural teamwork.[23] Allan and Chisholm's list of global competencies represents an especially well-developed set of attributes that are readily associated with technical coordination in global context, including a thoroughgoing emphasis on the importance of diversity awareness (including racial, cultural, ethnic, and linguistic) in relation to leadership, teamwork, and interpersonal communication competencies.[16] These authors also note the importance of global engineers embracing "culturally appropriate relationship-centred involvement in the global environments in which they work" and "support[ing] in their job role culturally aware developments and practices."[16]

Prior writings have also emphasized understanding and following global business norms and standards, as in Parkinson's discussion of the "international aspects of … business practices,"[18] Warnick's mention of "an ability to understand international business,"[21] and Ball et al.'s reference to "basic principles of global businesses."[23] Yet many of the materials we have reviewed focus instead on considerable contextual variations in management processes and professional conduct. For instance, cases by Acosta et al. and Shepherd help illustrate the difficulties and resistances that frequently emerge when organizations attempt to standardize corporate practices, processes, and values across disparate cultural contexts.[39,44] Hence, it is likely that the biggest difficulties facing engineers and other technical professionals center on cross-national *differences* in business practices rather than standards and commonalities.

As a typical example of technical coordination, one of our interviewees recounted a situation involving procurement of customized HVAC (heating, ventilation, and air conditioning) equipment for one of his company's facilities in China. Despite diligent work in advance to finalize detailed design specifications, the equipment was ultimately delivered with fans facing in the wrong direction. As the interviewee explained, this modification meant that the device was cheaper for the contractor to build, but would not perform as well once installed. While this clearly violated signed agreements with the supplier, our respondent recognized he was operating in a context where contracts are often viewed as more flexible and less sacrosanct, especially as compared to his country of origin (i.e., the U.S.).[45] Still other considerations were also taken into account, including costs associated with delaying installation of the equipment, expectations about the contractor being uncooperative if challenged, and additional technical analyses showing the equipment could be made to work. Based on all these factors, the interviewee decided to work around the design flaws in order to avoid a contract dispute and stay on schedule. Such realities are often faced when engineering work intersects with culture, requiring this engineer to perform deft acts of technical coordination involving a challenging mix of technical, business, and cultural considerations.

Another relevant question raised by such situations centers on the extent to which an engineer's technical knowledge, skills, and abilities are germane to effective technical coordination. As Trevelyan has argued, coordination itself is sometimes significantly non-technical, but nonetheless often requires considerable technical expertise and authority to establish one's legitimacy in various work settings.[35] We therefore acknowledge that some cases involving technical coordination might appear as though the associated engineering issues or technical context are somewhat incidental. While we return to this issue below, the sections that follow also highlight many instances where engineering or technical factors are centrally important.

Understanding and Negotiating Engineering Cultures

Many of the cases we have analyzed suggest that global engineers may encounter situations where multi-national/cultural differences in technical work practices are a critical consideration. To put it another way, such situations call for engineers who understand and are able to negotiate different "engineering cultures."[46] For example, Laroche's volume presents one case highlighting differences in Japanese and American understandings of technical standards, production quality, and organizational culture, and another case contrasting more theoretical versus practical approaches to technical problem solving among French and American engineers, respectively.[41] Other cases from Laroche reveal cross-national variations in divisions of expert labor, including different local expectations for what types of technical workers are responsible for setting up, maintaining, and/or running equipment. This same volume also discusses different expectations around the use of technical terms, such as a preference for very precise language among German engineers. Acosta et al. offer their own case contrasting differences in technical problem solving among French and Mexican production engineers, with the former trained as specialists who tend to value structure and procedure, and the latter as generalists who are adept at devising creative, *ad hoc* solutions.[39] Aesthetic considerations – which are often deeply rooted in history and culture – can also come into play when technical professionals do design work together, as illustrated in a case about the design and construction of the Water Cube structure for the 2008 Olympics in Beijing.[47]

Even more generally, the specific processes used to solve technical problems may be culturally inflected, which can generate conflict and controversy. For instance, a case by Thomke and Nimgade discusses problems caused by contrasting product development processes in Germany and India, while Hatvany and Pucik document considerable differences in how decision-making occurs in the U.S. and Japan.[48-49] Additionally, Acosta et al. have discussed how widespread – and often faulty – assumptions about "rational actor models" frequently influence strategic thinking and decision-making among Americans and many other Westerners, with significant implications for how technical work is coordinated and technical problems are approached.[39]

While the fundamental principles of engineering science may be immutable across the globe, the cases reviewed here indicate that engineers from different parts of the world often define and solve technical problems differently. Extensive historical and ethnographic research by Downey and Lucena offers further illustration of such issues, including by showing how national differences in engineering culture are often deeply rooted in earlier time periods and bound up with issues of national identity.[50-51] Further, many recent commentators and reports appear increasingly aware of these types of contextual factors. For example, the aforementioned 1999 NRC report was prescient in this regard when it highlighted the importance of "knowledge of the business and engineering cultures of counterpart countries."[10] More recent variations on this theme include statements stressing the importance of: "Applying engineering solutions and applications within a global context,"[12] "[A]nalyz[ing] how national differences are important in engineering work,"[51] "Socio/political impact on problem definition,"[14] "Understand[ing] implications of cultural differences on how engineering tasks might be approached,"[18] and "Understand[ing] cultural differences relating to product design, manufacture and use."[18]

Similar themes surfaced in our interviews, particularly as individuals reflected on how their own prior training and work experiences inflected their approaches to problem solving. For example, one of our subjects noted the importance of both "structured thinking" and "lateral thinking" in technical work, yet explained that the former was primarily emphasized in the type of education he received in his native country (India). As a result, he realized that in one of his consulting assignments he was narrowly focused on refining and optimizing an existing process instead of asking more fundamental questions about whether the process itself was appropriate or state-of-the-art. Similar themes surfaced in one of our previous studies, in which a number of engineering students in a summer research abroad program observed that their Chinese counterparts were sometimes reluctant to question their fundamental assumptions or revisit first principles.[52] Such findings help highlight how technical work is often inflected by local and regional styles of education and training, including a greater tendency toward rote learning and narrow analytic problem solving in many Asian settings. When engineers encounter such differences, responding appropriately frequently requires heightened awareness, understanding, and sensitivity.

Navigating Ethics, Standards, and Regulations

The literature examined thus far also reveals a cluster of cases involving various ethical issues in global technical work, beginning with some notable examples drawn from engineering ethics textbooks. One of the more prominent ethical topics in this domain centers on gift giving and bribery, as illustrated through two cases by Humphreys focused on China, and a brief hypothetical scenario by Robinson et al. that is international in nature but does not specify a specific host country.[53-54] Additionally, a chapter in an ethics textbook by Harris et al. presents cases covering a wider variety of issues that cut across many geographic contexts, including lax pollution standards, corporate paternalism, nepotism, tax avoidance, workplace conditions, and employee remuneration.[55] A multimedia case by Raju and Sankar, on the other hand, highlights the importance of global engineering standards, and explores issues of corporate and professional responsibility when problems surface in multi-national design projects.[56]

While most of these cases can be categorized as what Herkert calls "micro-ethical" situations because of their primary focus on individual conduct, other writers have emphasized "macro-ethical" issues that involve larger questions of collective, social responsibility.[57] Most notably, Vesilind and Gunn present cases involving human rights issues and environmental racism, while Lawrence and Tolley present a case focused on human rights concerns surfacing around infrastructure projects in the formerly authoritarian state of Myanmar.[58-59] The rise of international service learning and professional outreach activities in engineering, as exemplified by organizations like Engineers Without Borders, has also been accompanied by publication of a small number of case studies highlighting some of the moral and macro-ethical issues associated with first-world engineers working in developing country contexts.[60-61]

Additionally, reviewing the extant literature on global competency in engineering suggests widespread agreement that practicing engineers should be aware of different local expectations about what counts as ethical engineering practice. The ASCE, for instance, notes "[t]he challenge of practicing ethically in a global environment,"[26] while Parkinson states that engineers should be ready to "effectively deal with ethical issues arising from cultural or national differences."[18] Mohtar and Dare similarly stress "[t]he ability to make ethical and socially responsible decisions in the context of a culture divergent from my own,"[24] while Ragusa more generally emphasizes "moral responsibility to improve conditions and take action in diverse engineering settings."[62]

Questions about standards and regulations also surface in this literature, including the extent to which engineers are obligated to meet legal and other policy obligations prevailing in their home and/or host country contexts. Mohtar and Dare frame this issue in terms of "awareness of varying regulations, codes of practice, standards, technical specifications, testing/inspection procedures, environmental regulations, and systems of measurement between countries and regions,"[24] while Patil notes the salience of "[i]nternational labor market and workplace imperatives."[12] Parkinson adds that global engineers should "[h]ave some exposure to international aspects of topics such as supply chain management, intellectual property, liability and risk, and business practices."[18] Given that decisions about whether to follow particular regulatory guidelines or frameworks often involve ethical or moral considerations, we place them in the same overarching category.

Our research subjects also shared many relevant situations involving issues ranging from export control and intellectual property considerations to health, safety, and environmental concerns. As a representative example, one of our interviewees described a major project in Egypt where "the first guy on the site was driving a backhoe and … he not only had sandals on but his ten-year-old son who was sitting on his lap had sandals on." As he pointed out, this situation revealed marked differences between accepted local work practices and his company's strong orientation toward a "safety culture." Sensitively and proactively negotiating such differences can pose considerable challenges for the global engineer.

CONCLUSIONS AND FUTURE WORK

The preceding account begins to map out the contours of the domain we call global engineering competency. It is also worth reiterating how the three dimensions described above are related. *Technical coordination* refers to situations where negotiating social relationships and finding effective communication strategies in multi-national/cultural settings are dominant considerations. Additionally, only cases involving *technical experts* and/or *technical problems* are defined as relevant to this domain, as otherwise they would fall into the more general realm of cross-cultural business or management situations. *Engineering cultures* situations, on the other hand, are defined by multi-national/cultural differences in the actual practices and processes of technical problem solving. Here, technical expertise and technical problems are generally at the forefront. Finally, situations in the *ethics, standards, and regulations* category occur when technical coordination or technical problem solving happen in the midst of multiple – and often conflicting – normative and/or policy contexts.

While these three dimensions have emerged as most prevalent in our data collection and analysis, additional themes have also surfaced. For example, *knowledge brokering* and *boundary spanning* capabilities have been described in a handful of case studies, including Johri's research on global software engineers and DiMarco et al.'s study of global engineering project networks.[63-64] We will continue probing these areas in our work, possibly as additional sub-dimensions of technical coordination. Additionally, we still have much work to do in triangulating the literature reviewed above with the qualitative interview data we have collected. In so doing, we will continue firming up our core domains of interest, including by developing a more robust theoretical understanding of what specific underlying attributes (i.e., knowledge, skills, attitudes, abilities, and other characteristics) are linked to effective performance in each domain.

Our efforts are also supporting another core project objective, namely generating a situational judgment test (SJT) designed to evaluate multiple dimensions of global engineering competency across a variety of national/cultural contexts. Creating this multiple-choice assessment tool involves a systematic, iterative process of generating item stems and response options, inspired by both the literature reviewed above and our interview data. Further background details regarding scenario-based and situational approaches to assessment appear elsewhere.[65] We expect the final version of the instrument will feature 15-20 questions covering the three dimensions of global engineering competency described above, as well as six specific national/cultural contexts (Japan, China, India, France, Germany, and Mexico). These countries were selected based on a combination of factors: 1) prevalence in the empirical data collected for this project, 2) status as top ranking world economies (as measured by GDP), 3) status as leading or rising economies for R&D spending, and 4) intensity of trade relations with the U.S. Figure 2 presents a sample SJT-style assessment question that was developed and piloted during the preliminary phases of this project. This scenario falls in the domain of technical coordination, and is designed to evaluate the extent to which respondents can pick both appropriate and inappropriate behavioral responses, including by both drawing on relevant *knowledge* (e.g., understanding the concept of "saving face" in East Asian cultures) and reflecting appropriate *attitudes* (e.g., cultural sensitivity). We propose that placing a quality control issue at the heart of this scenario grounds the situation in a salient technical context that is very familiar to engineers and other technical professionals. Our initial use of this question as a discussion prompt in the context of courses and workshops, as well as in individual and focus group interviews with subject matter experts, suggests that the scenario is typically viewed as plausible and relevant.

As an employee in a large multinational corporation, you are temporarily assigned to your company's branch operations in Shanghai, China. You are a member of a team consisting of three Chinese engineers, all about the same rank as you. Your team reports to an engineering manager, who is also Chinese. You are in a team meeting where your manager proposes a solution to a difficult quality control problem. However, you are concerned that the proposed solution will fail. Consider these possible actions:

a) Have the entire team approach the manager together.
b) Bring up your concerns in the meeting.
c) Set aside your concerns and follow the manager's lead.
d) Discuss the issue with the manager later, in a private meeting.
e) Consult your Chinese team members about appropriate actions to take.
f) Discuss your concerns with a higher-ranking manager.

Which of these actions (a-f) would you MOST likely take? Which of these actions (a-f) would you LEAST likely take?

Figure 2. Sample Situational Assessment Question for Global Engineering Competency

This same scenario prompt was also used by the lead author to write a longer script that more completely illustrates how this type of work situation might play out in a real-world setting. The script was acted out by a group of graduate students, and the resulting video clips were edited to create Global Engineering Competency Vignette #1, as shown in Figure 3. This brief video (less than three minutes) is intended for use in courses and workshops where instructors wish to seed and facilitate case-based conversations about typical

Figure 3. Screen Capture from Global Engineering Competency Vignette #1[66]

situations and behavioral expectations in global engineering work. The video and an instructor's guide are freely available on YouTube.[66]

Facing the realities of an increasingly globalized world, many universities and companies are looking for ways to more effectively select, develop, and manage engineers and other technical professionals who can successfully work across national and cultural boundaries. The larger project represented by this paper offers critical support for such an undertaking, including by contributing to establishment of a more robust definition of global engineering competency that can inform creation of high quality assessment instruments and high impact instructional interventions. Ultimately, success in our efforts will mean marked increases in the number of engineering graduates and professionals who are ready – and even eager – to face the world.

ACKNOWLEDGMENTS

An earlier version of this paper appeared in the Proceedings of the 2013 ASEE International Forum, Atlanta, GA, June 22, 2013. All unmodified portions of this paper are republished with permission from the American Society for Engineering Education (ASEE), the original copyright holder. The authors gratefully acknowledge support for aspects of this work under National Science Foundation (NSF) grant EEC-1160455, "Global Engineering Competency: Definitions, Development Paths, and Situational Assessment." We extend appreciation to affiliates of the Global Engineering Education Collaboratory (GEEC) for their extensive assistance with this project, and anonymous reviewers whose thoughtful feedback helped us improve the final draft.

REFERENCES

[1] Jesiek, B. K., and Beddoes, K. From Diplomacy and Development to Competitiveness and Globalization: Historical Perspectives on the Internationalization of Engineering Education. In Downey, G. L., and Beddoes, K. (Eds.), What is Global Engineering Education For?: The Making of International Educators (45-76). Morgan and Claypool, San Rafael, CA. 2010.

[2] Johri, A. Situated Engineering in the Workplace. Engineering Studies, 2010. 2(3): 151-152.

[3] Trevelyan, J. Published Research on Engineering Work. Journal of Professional Issues in Engineering Education and Practice. 2007. 133(4): 300-307.

[4] National Academy of Engineering and Office of International Affairs, National Research Council. Strengthening U.S. Engineering Through International Cooperation: Some Recommendations for Action. National Academy of Engineering, Washington, DC. 1987.

[5] Wulf, W. 2003 Annual Meeting – President's Remarks. National Academy of Engineering, Washington, DC. 2003. Available at http://www.nae.edu/News/SpeechesandRemarks/page2003AnnualMeeting-PresidentsRemarks.aspx

[6] Katehi, L. The Global Engineer. In Educating the Engineer of 2020 (151-155). National Academy Press, Washington, DC. 2005.

[7] Global Engineering Excellence Initiative (GEEI). In Search of Global Engineering Excellence: Educating the Next Generation of Engineers for the Global Workplace. Continental AG, Hanover, Germany. 2006.

[8] Sigma Xi. Embracing Globalization: Assuring a Globally Engaged Science and Engineering Workforce (Workshop Report). Sigma Xi, Washington, DC. 2007.

[9] Grandin, J., and Hirleman, E. D. Educating Engineers as Global Citizens: A Call for Action / A Report of the National Summit Meeting on the Globalization of Engineering Education. Online Journal of Global Engineering Education. 2009. 4(1): 1-28.

[10] National Research Council. Engineering Education Tasks for the New Century: Japanese and U.S. Perspectives. National Academy Press, Washington, DC. 1999.

[11] The Boeing Company and Rensselaer Polytechnic Institute (RPI). A Manifesto for Global Engineering Education: Summary Report of the Engineering Futures Conference, January 22–23, 1997. 1997.

[12] Patil, A. Global Engineering Criteria for the Development of the Global Engineering Profession. World Transactions on Engineering and Technology Education. 2005. 4(1): 49-52.

[13] Lohmann, J., Rollins, H., and Hoey, J. Defining, Developing, and Assessing Global Competence in Engineers. European Journal of Engineering Education. 2006. 31(1): 119-131.

[14] Allert, B., Atkinson, D., Groll, E., and Hirleman, E. D. Making the Case for Global Engineering: Building Foreign Language Collaborations for Designing, Implementing, and Assessing Programs. Online Journal for Global Engineering Education. 2007. 2(2): 1-14.

[15] Sigma Xi. Developing Evaluation Approaches to International Collaborative Science and Engineering Activities (Workshop Report). Sigma Xi, Washington, DC. 2008.

[16] Allan, M., and Chisholm, C. U. Achieving Engineering Competencies in the Global Information Society Through the Integration of On-Campus and Workplace Environments. Industry and Higher Education. 2008. 22(3): 145-152.

[17] Parkinson, A., Harb, J., Magleby, S. Developing Global Competence in Engineers: What Does It Mean? What is Most Important? Proceedings of the 2009 ASEE Annual Conference and Exposition, Austin, TX, June 14-17, 2009.

[18] Parkinson, A. The Rationale for Developing Global Competence. Online Journal of Global Engineering Education. 2009. 4(2): 1-15.

[19] Grandin J. M., and Hedderich, N. Intercultural Competence in Engineering: Global Competence for Engineers. In Deardorff, D. K. (Ed.), The SAGE Handbook of Intercultural Competence (362-372). SAGE Publications, Inc., Thousand Oaks, CA and London. 2009.

[20] Jesiek, B. K., Sangam, D., Thompson, J., Chang, Y., and Evangelou, D. Global Engineering Attributes and Attainment Pathways: A Study of Student Perceptions. Proceedings of the 2010 ASEE Annual Conference and Exposition, Louisville, KY, June 20-23, 2010.

[21] Warnick, G. M. Global Competence: Determination of its Importance for Engineers Working in a Global Environment. Educational Administration: Theses, Dissertations, and Student Research, Paper 35. University of Nebraska – Lincoln, Lincoln, NE. 2010. Available at http://digitalcommons.unl.edu/cehsedaddiss/35 2010

[22] International Federation of Engineering Education Societies (IFEES). The Attributes of a Global Engineer Project. IFEES, Milwaukee, WI. 2013. Available at http://www.sefi.be/ifees/wp-content/uploads/WEEF-2012-Attributes-of-a-Global-Engineer.pdf

[23] Ball, A. G., Zaugg, H., Davies, R., Tateishi, I., Parkinson, A. R., Gensen, C. G., and Magleby, S. P. Identification and Validation of a Set of Global Competencies for Engineering Students. International Journal of Engineering Education. 2012. 28(1): 156-168.

[24] Mohtar, R. H., and Dare, A. E. Global Design Team: A Global Service-Learning Experience. International Journal of Engineering Education. 2012. 28(1): 169-182.

[25] ABET Engineering Accreditation Commission (EAC). Criteria for Accrediting Engineering Programs: Effective for Reviews During the 2012-2013 Accreditation Cycle. ABET, Inc., Baltimore, MD. 2011.

[26] American Society of Civil Engineers (ASCE), Body of Knowledge Committee of the Committee on Academic Prerequisites for Professional Practice. Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer of the Future (Second Edition). American Society of Civil Engineers, Reston, VA. 2008.

[27] Engineers Australia (EA). Guide to Assessment of Eligibility for Membership (Stage One Competency). Engineers Australia, Barton, ACT, Australia. 2010.

[28] European Network for Accreditation of Engineering Education (ENAEE). EUR-ACE Framework Standards for the Accreditation of Engineering Programmes. ENAEE, Brussels, Belgium. 2008.

[29] Lucia, A. D., and Lepsinger, R. The Art and Science of Competency Models: Pinpointing Critical Success Factors in Organizations. Jossey-Bass/Pfeiffer, San Francisco, CA. 1999.

[30] Johri, A., and Jesiek, B. K. Global and International Issues in Engineering Education. In Olds, B. M., and Johri, A. (Eds.), Cambridge Handbook of Engineering Education Research (CHEER). Cambridge University Press, Cambridge, UK. Forthcoming.

[31] Cheetham, G., and Chivers, G. E. Professions, Competence and Informal Learning. Edward Elgar Publishing, Inc., Cheltenham, Glos, UK and Northampton, MA, USA. 2005.

[32] Lucena, J. What is Engineering for? A Search for Engineering beyond Militarism and Free-markets. In Downey, G. L., and Beddoes, K. (Eds.), What is Global Engineering Education For?: The Making of International Educators (361-383). Morgan and Claypool, San Rafael, CA. 2010.

[33] Walther, J., Kellam, N., Sochacka, N., and Radcliffe, D. Engineering Competence? An Interpretive Investigation of Engineering Students' Professional Formation. Journal of Engineering Education. 2011. 100(4): 703-740.

[34] Flanagan, J. The Critical Incident Technique. Psychological Bulletin. 1954. 51: 327–358.

[35] Trevelyan, J. Technical Coordination in Engineering Practice. Journal of Engineering Education. 2007. 96(3): 191-204.

[36] Trevelyan, J. Reconstructing Engineering from Practice. Engineering Studies. 2010. 2(3): 175-195.

[37] Dierdorff, E., Rubin, R., and Morgeson, F. The Milieu of Managerial Work: An Integrative Framework Linking Work Context to Role Requirements. Journal of Applied Psychology. 2009. 94(4): 972-988.

38 Gibbons, A. M., Rupp, D. E., Snyder, L. A., Holub, A. S., and Woo, S. E. A Preliminary Investigation of Developable Dimensions. Psychologist Manager Journal. 2006. 9(2): 99-123.

39 Acosta, C., Leon, V. J., Conrad, C., and Malave, C. O. Global Engineering: Design, Decision Making, and Communication. CRC Press, Boca Raton, FL. 2010.

40 Hofstede, G., and Hofstede, G. J. Cultures and Organizations: Software of the Mind (2nd Edition). McGraw-Hill, New York, NY. 2005.

41 Laroche, L. Managing Cultural Diversity in Technical Professions. Butterworth-Heinemann, Burlington, MA. 2003.

42 Yemen, G., and Isabella, L. A. Cisco Switches in China: The Year of the Manager. Darden Business Publishing, University of Virginia, Charlottesville, VA. Available at http://hbr.org/product/cisco-switches-in-china-the-year-of-the-manager/an/UV4292-PDF-ENG (accessed March 11, 2013)

43 Storti, C. Cross-Cultural Dialogues: 74 Brief Encounters With Cultural Difference. Intercultural Press, Inc., Yarmouth, ME. 1994.

44 Shepherd, D. Case 1.3: Common Bond Values at the New Zealand Office of AT&T. In Thomas, D. C. (Ed.), Readings and Cases in International Management: A Cross-Cultural Perspective (92-100). SAGE Publications, Inc., Thousand Oaks, CA and London. 2003.

45 Zinzius, B. Doing Business in the New China: A Handbook and Guide. Praeger Publishers, Westport, CT. 2004.

46 Downey, G., and Lucena, J. C. Knowledge and Professional Identity in Engineering: Code-Switching and Metrics of Progress. History and Technology: An International Journal. 2004. 20(4): 393-420.

47 Eccles, R. G., Edmondson, A. C., and Karadzhova, D. Arup: Building the Water Cube. Harvard Business School, Boston, MA. Available at http://hbr.org/product/arup-building-the-water-cube/an/410054-PDF-ENG (accessed March 11, 2013)

48 Thomke, S., and Nimgade, A. Siemens AG: Global Development Strategy (A). Harvard Business School, Boston, MA. Available at http://hbr.org/product/siemens-ag-global-development-strategy-a/an/602061-PDF-ENG (accessed March 11, 2013)

49 Hatvany, N., and Pucik, V. Case 1.7: Chiba International, Inc. In Thomas, D. C. (Ed.), Readings and Cases in International Management: A Cross-Cultural Perspective (115-122). SAGE Publications, Inc., Thousand Oaks, CA and London. 2003.

50 Downey, G., and Lucena, J. C. National Identities in Multinational Worlds: Engineers and ‘Engineering Cultures.’ International Journal of Continuing Engineering Education and Lifelong Learning. 2005. 15(3-6): 252-260.

51 Downey, G., Lucena, J. C., Moskal, B., Bigley, T., Hays, C., Jesiek, B., Kelly, L., Lehr, J., Miller, J., Nichols-Belo, A., Ruff, S., and Parkhurst, R. The Globally Competent Engineer: Working Effectively with People Who Define Problems Differently. Journal of Engineering Education. 2006. 105(2): 107-122.

52 Jesiek, B. K., Haller, Y., and Thompson, J. Developing Globally Competent Engineering Researchers: Outcomes-Based Instructional and Assessment Strategies from the IREE 2010 China Research Abroad Program. Advances in Engineering Education, forthcoming.

53 Humphreys, K. What Every Engineer Should Know about Ethics. Marcel Dekker, Inc., New York, NY. 1999.

54 Robinson, S., Dixon, R, Preece, C., and Moodley, K. Engineering, Business, and Professional Ethics. Butterworth-Heinemann, Oxford, UK. 2007.

55 Harris, C. E., Jr., Pritchard, M. S., Rabins, M. J., Ray, J., and Englehardt, E. Engineering Ethics: Concepts and Cases (5th Edition). Wadsworth, Cengage Learning, Boston, MA. 2013.

56 Raju, P. K., and Sankar, C. S. Mauritius Auditorium Design Case Study. Available at http://liteecases.com/mauritius-auditorium-design-case-study/ (accessed February 17, 2014)

[57] Herkert, J. Professional Societies, Microethics, and Macroethics: Product Liability as an Ethical Issue in Engineering Design. International Journal of Engineering Education. 2003. 19(1): 163-167.

[58] Vesilind, P. A., and Gunn, A. S. Hold Paramount: The Engineer's Responsibility to Society (Second Edition). Cengage Learning, Stamford, CT. 2011.

[59] Lawrence, A. T., and Tolley, H. Jr. Case 1.2: Unocol and the Yadana Gas Pipeline Project. In Thomas, D. C. (Ed.), Readings and Cases in International Management: A Cross-cultural Perspective (75-91). Sage Publications, Thousand Oaks, CA. 2003.

[60] Lucena, J., Schneider, J., and Leydens, J. Engineering and Sustainable Community Development. Morgan and Claypool, San Rafael, CA. 2010.

[61] Nieusma, D., and Riley, D. Designs on Development: Engineering, Globalization, and Social Justice. Engineering Studies. 2010. 2(1): 29-59.

[62] Ragusa, G. Engineering Preparedness for Global Workforces: Curricular Connections and Experiential Impacts. Proceedings of the 2011 ASEE Annual Conference and Exposition, Vancouver, BC, Canada, June 26-29, 2011.

[63] Johri, A. Boundary Spanning Knowledge Broker: An Emerging Role in Global Engineering Firms. Proceedings of the 38th Annual Frontiers in Education Conference, Saratoga Springs, NY, October 25-28, 2008.

[64] Di Marco, M. K., Taylor, J. E., and Alin, P. Emergence and Role of Cultural Boundary Spanners in Global Engineering Project Networks. Journal of Management in Engineering. 2010. 26(3): 123-132.

[65] Jesiek, B. K, and Woo, S. E. Realistic Assessment for Realistic Instruction: Situational Assessment Strategies for Engineering Education and Practice. Proceedings of the 2011 SEFI Annual Conference, Lisbon, Portugal, September 27-30, 2011.

[66] Jesiek, B. K. Global Engineering Competency Vignette #1. 2013. Available at http://www.youtube.com/watch?v=Hbat8X96m9g (accessed July 27, 2013)