AC 2009-571: DEVELOPING GLOBAL COMPETENCE IN ENGINEERS: WHAT DOES IT MEAN? WHAT IS MOST IMPORTANT?

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Abstract

A number of recent reports on the future of engineering education recommend that engineers develop "global competence." Although this term is becoming more widely used, it isn't always clear what it means. In this paper, we propose and define 13 dimensions or attributes of global competence. We report on the results of a survey of engineering educators and industry representatives on the importance of these attributes. This survey was initially conducted as part of a National Science Foundation sponsored summit on global engineering education.

Introduction: Why Global Competence?

In this paper we discuss what it means for engineers to develop global competence and why such competence is important. The globalization of engineering has been the result of a confluence of forces and changes taking place over the past two decades. [1] Perhaps ironically, technology developed by engineers has been a main driving force acting to change engineering practice. For example, advances in telecommunications now make possible inexpensive, real-time communication virtually anywhere in the world. Although now considered commonplace, this is a monumental achievement in the history of humankind. Worldwide communications have been accompanied by the development of low cost computing and the rise of the Internet as a means for organizing and sharing data.

Along with technology, major geopolitical and economic changes have also facilitated the globalization of engineering. The past 20 years have seen the dissolution of the Soviet Union, whereby the 15 member states declared their independence and moved toward open societies and market economies. The European Union was formed and has become one of the largest single markets in the world, with a combined $17 trillion economy.[2] China and India, representing more than one third of the world's population, have become important players in global markets and technology development. Across the world, free trade barriers have dropped, and the influence of multi-national corporations has increased.[3]

As a result of these changes, product design and manufacture often cut across national boundaries. It is not uncommon for companies to develop products with teams that include members located throughout the world. These teams may reflect high cultural and national diversity. The products they design will often be for sale in numerous countries and therefore must address customer needs in those countries. Products may be manufactured abroad, with raw materials or sub-assemblies coming from various parts of the world. These changes require that engineers be able to work in a diverse, multi-national and multi-cultural environment.

Besides these influences, however, perhaps the most compelling reason for global competence relates to the nature and scope of the problems faced by humankind. Recently, for example, the National Academy of Engineering issued a list of grand challenges for engineering. [4] Many of these are global in scope and relate to sustaining life on the planet, such as making solar energy economical, providing energy from fusion, developing carbon

sequestration methods, managing the nitrogen cycle, providing access to clean water, restoring and improving urban infrastructure, and preventing nuclear terror. These are critical problems which cut across ethnic, cultural and national boundaries, and they will require cooperation among nations and peoples if they are to be solved.

Global Competence: What Does It Mean?

In light of these developments, numerous reports and studies indicate that engineers need to be able to work in a global context. This ability is referred to by a number of terms, such as global citizenship, global perspective, cross-cultural or intercultural competence, global awareness, or, more frequently, *global competence*. Although the terminology seems to be converging, it is not clear that the definition of these terms has followed suit. For example, Grudzinski et al. note that "global citizenship" is a term used with increasing frequency to denote "a wide range of educational and philosophical aims."[5] Grandin and Hedderich discuss various definitions for global competence and comment on the "elusive" nature of this term. [6] If this ability is to be taught, developed and assessed, it must first be clearly defined.

In this section we will review some of the definitions given in the literature. We start with some general definitions that apply across many disciplines. We then become more specific and look at definitions more focused on engineering. These definitions are presented in part to show the broad scope of knowledge and abilities encompassed by these terms.

Deardorff interviewed 23 scholars in the field of intercultural education to obtain both a definition and a better understanding of the specific skills involved in "intercultural competence."[7] Among several definitions given, one of the most highly rated was,

> Five components: World knowledge, foreign language proficiency, cultural empathy, approval of foreign people and cultures, and ability to practice one's profession in an international setting.

We note that the last component, "the ability to practice one's profession…" could clearly involve a number of more specific attributes.

Hunter gives a definition developed by community college officials for a "globally competent learner,"[8]

> a globally competent learner is one who is able to understand the interconnectedness of peoples and systems, to have a general knowledge of history and world events, to accept and cope with the existence of different cultural values and attitudes and, indeed, to celebrate the richness and benefits of this diversity.

In terms of global competence for engineers, the definitions tend to be somewhat more specific. Some authors indirectly define this term by listing the attributes they believe students should develop. For example, James Duderstadt, former president and dean of engineering at the University of Michigan, described a competency that he called "global perspective:" [9]

> …it is important to stress the importance of a *global perspective* for engineering practice. Key is not only a deep understanding of global markets and organizations, but the capacity to work in multidisciplinary teams characterized by high cultural diversity, while exhibiting the nimbleness and mobility to address rapidly changing global challenges and opportunities.

Patricia Galloway, former president of the American Society of Civil Engineers, also lists some of the attributes required of engineers in her book, *The 21st Century Engineer, A Proposal for Engineering Reform*.[10] She writes,

> A solid understanding of globalization is key to an engineer's success in today's global society. Globalization involves the ability to understand that the world economy has become tightly linked with much of the change triggered by technology; to understand other cultures, especially the societal elements of these cultures; to work effectively in multinational teams; to communicate effectively—both orally and in writing—in the international business language of English; to recognize and understand issues of sustainability; to understand the importance of transparency while working with local populations; and to understand public policy issues around the world and in the country in which one is working. It will be these fundamental capacities that will enable 21st-century engineers to develop into professionals capable of working successfully both domestically and globally, highly respected by the general public and regarded…the world over as professionals of the highest order.

Lohmann et al. discuss the wide scope of attributes which can be implied by the term "global competence." They attempt to boil these down to three main areas,[11]

> While these trends suggest a rather daunting educational challenge to prepare engineers for such a multifaceted engineering environment, three new skills and abilities required of future engineers seem to emerge from much of the conversation. First engineers need a broader multidisciplinary base of knowledge, especially in fields that were traditionally viewed as tangential to engineering education, such as global socio-economic and political systems, international commerce and world markets, environmental systems and research and technological innovation….Second, engineers need more refined and diverse interpersonal skills, particularly in global collaborations….Finally, engineers need the ability to live and work comfortably in a transnational engineering environment.

As definitions of global competence are made more specific and are focused on engineers in particular, some of the characteristics of engineering profession come into play. For example, engineers are often considered to be problem solvers. Thus, Downey et al. discuss global competence for engineers primarily in terms of being able to work effectively with someone who defines problems differently:[12]

> …the key achievement in the often-stated goal of working effectively with different cultures is learning to work effectively with people who define problems differently than oneself.
>
> …the proposed learning criterion for the global competency of engineering students is as follows: *Through course instruction and interactions, students will acquire the knowledge, ability, and predisposition to work effectively with people who define problems differently than they do.*

Many engineers work in some facet of product design or manufacturing. Product development often involves collaboration with geographically diverse teams and may involve remote manufacturing. Sanders and Patro provide a list of attributes that seem to refer to this part of engineering,[13]

> "The future successful engineer will be one who:
> - Will have a thorough knowledge and experience in working with complex supply chain networks.
> - Can effectively function in a multi-cultural environment or as part of a multi-cultural team
> - Is trained to quickly adapt to advancements in collaborative technology.

Thirteen Dimensions of Global Competence

As the previous discussion shows, global competence can involve a wide range of skills and abilities. Based on these definitions, experience with our own study abroad programs, and stated objectives of courses and programs which prepare students to be globally competent, in this section we propose 13 distinct dimensions or attributes of global competence. First we define and explain these dimensions. Then we discuss the relative importance of these attributes.

Global Competence means engineering graduates,

1. Can appreciate other cultures.

   Explanation: This attribute is focused partly on understanding and avoiding *ethnocentrism*, the idea that one's own culture is superior to all others. "All cultures, to some degree, display ethnocentrism, which can be the greatest single obstacle to understanding another culture."[14] Engineers may be susceptible to a particular form of ethnocentrism: the assumption that if their country is more technologically advanced, their culture must be superior. This may more of a problem for U.S. engineers, since the U.S. has been considered to be the world's only superpower for some time. Engineering graduates need to be aware of these potential problems and develop the capacity to appreciate and be sensitive to other cultures.

2. Are able to communicate across cultures.

Explanation: Communication in some form is the foundation upon which most engineering activities build. Communication across cultures includes understanding cultural differences regarding such things as status, formality, saving face, directness, the meaning of "yes", non-verbal cues, etc. To avoid misunderstandings or outright communication breakdowns, the substantial influence of culture on how people communicate should be understood.

3. Are familiar with the history, government and economic systems of several target countries.

   Explanation: This dimension refers to understanding important elements of the context of a society. For example, how is understanding the aggressive market economy of present day China enhanced by knowing about the cultural revolution of the 1960's and 70's? As students visit factories in China owned by Taiwanese companies, how is their appreciation of this situation deepened by knowing the history of China and Taiwan?

4. Speak a second language at a conversational level.

   Explanation: Although U.S. engineers are fortunate in that much of the world speaks English, learning the language of another country is key in developing a deep understanding of the culture and is an impressive gesture of goodwill and reaching out to cross cultural boundaries. Learning a second language also promotes tolerance for others who have learned English as a second language.

5. Speak a second language at a professional (i.e. technical) level.

   Explanation: This attribute takes Dimension 4 a step further to being able to conduct engineering activities in a second language. This allows for further understanding of cultural issues associated with engineering tasks and provides a significant reduction in the possibility of misunderstandings arising from poor translations or cultural gaps.

6. Are proficient working in or directing a team of ethnic and cultural diversity.

   Explanation: Much engineering work is conducted in teams. As engineering work becomes more global in nature, engineering teams become more diverse and may include members of various ethnic, cultural and national origins. Developing this attribute relies heavily on developing communication skills across cultures (Dimension 2).

7. Can effectively deal with ethical issues arising from cultural or national differences.

   Explanation: Ethical issues can be magnified when cultural issues come into play. For example, it is common in some cultures or countries for business to be conducted via bribes or kickbacks. Tax evasion may be rampant. Whereas in the U.S. such conduct is considered to be unethical and illegal, how does an engineer approach

these issues in a society that does not feel this way? Similar issues come up relative to safety. Standards for safety or environmental protection vary widely across national boundaries. What standards should U.S. engineers follow in situations where regulations are much looser than in the U.S.?

8. Understand cultural differences relating to product design, manufacture and use.

   Explanation: Being global often means designing, manufacturing and selling products in multiple countries. A deep understanding of customer needs can be heavily influenced by cultural values. For example, if a company design refrigerators, how might designs for Europe be different than for the U.S. by understanding that Europeans shop for fresh fruits and vegetables almost every day?

9. Have an understanding of the connectedness of the world and the workings of the global economy.

   Explanation: This dimension relates to having a basic understanding that the world's economies are now very interconnected. How does demand for commodities in China affect prices in the U.S.? How do interest rates in Europe affect the exchange rate between the Euro and the dollar? How do exchange rates affect exports?

10. Understand implications of cultural differences on how engineering tasks might be approached.

    Explanation: This dimension is closely related to the attribute of being able to work in diverse teams. As an example, how does the notion of time in a particular culture affect how closely a schedule is followed? How does culture affect how design decisions are made? How might various cultures approach the solution of the same problem?

11. Have some exposure to international aspects of topics such as supply chain management, intellectual property, liability and risk, and business practices.

    Explanation: These are all topics which can directly affect doing business abroad.

12. Have had a chance to practice engineering in a global context, whether through an international internship, a service-learning opportunity, a virtual global engineering project or some other form of experience.

    Explanation: Whereas the other attributes focus on knowledge or understanding, this dimension focuses on practice. Many of the above attributes have to be practiced to achieve competence.

13. View themselves as "citizens of the world," as well as citizens of a particular country; appreciate challenges facing mankind such as sustainability, environmental protection, poverty, security, and public health.

Explanation: As suggested by the Grand Challenges of the National Academy of Engineering, many of the greatest technical challenges facing humankind cut across national boundaries, such as energy production, environmental protection, access to clean water, and security. Solution to these problems will require cooperation among peoples and nations. Graduates need to take responsibility for and understand the impact of their decisions on the sustainability of the planet.

Global Competence: What is Most Important?

Survey Results

To gain further insight into the attributes of global competence, a survey of their relative importance was conducted of persons in academia and industry. The survey asked respondents to evaluate each attribute according to the scale, 1—Not important, 2—Of Some Advantage, 3—Desirable, 4—Highly Desirable, 5—Essential.

The purpose of the survey was twofold. First, we wanted to determine if the list is complete, i.e., is everything on the list important, and/or has anything been left out? Second, we wanted to determine the relative importance of the items on the list. Are some dimensions more important than others? The 13 attributes cover a broad set of skills and knowledge. If universities cannot develop all of these, which elements should they focus on?

Surveys were sent to attendees to the NSF Summit on the Globalization held at the University of Rhode Island, Nov 5-6, 2008. Since the attendees were primarily from universities, they were asked to distribute the survey to one or two industry contacts in order to obtain industry feedback. The survey was completed by 15 individuals from 11 universities, 14 individuals representing 12 companies, and two respondents from government or ASEE.

The university respondents all held positions which would involve them in this issue, such as engineering deans, chairs, study abroad directors, or other university administrators. Thus it was to be expected that they would feel global competence was important. All of the industry respondents worked at the management level (several were retired) for companies which have global operations. Besides indicating how essential each attribute is to global competence, industry respondents also answered the question, “How important is it that the engineering graduates of today (in many cases, your own employees) are globally competent? The same scale was used to answer this question.

The relative importance of the attributes is shown in Figure 1, with separate bars for academia and industry. The chart shows relatively consistent rankings, given the small sample size, across academia and industry. Tables 1, 2, and 3 give the rankings by academia, industry, and the total of the two, respectively. Four of the top five attributes are common between the two groups. The one difference is academic respondents ranked “View themselves as citizens of the world…” in the top five whereas industry respondents included “Deals effectively with ethical issues...” in the top five attributes instead.

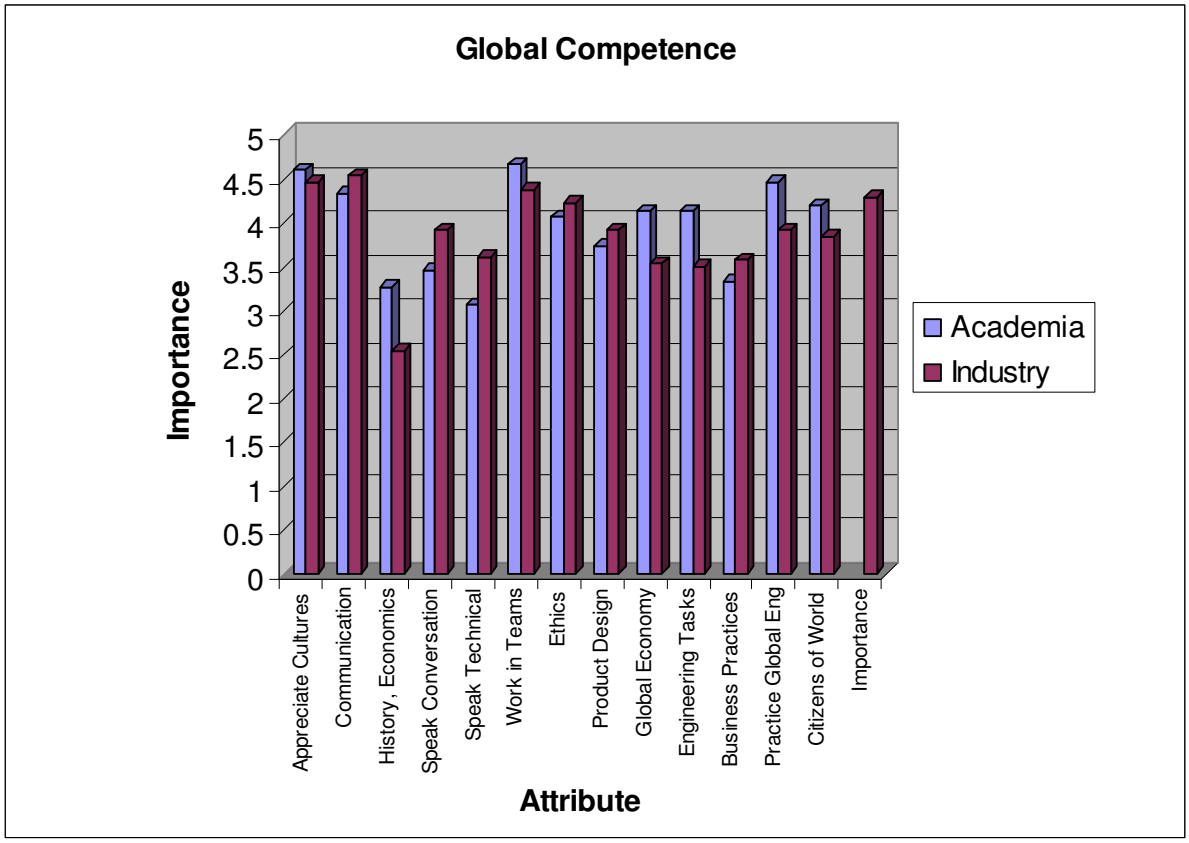

Fig. 1. Relative importance of 13 dimensions of global competence as ranked by academia and industry.

Table 4. Ranking of Attributes by Academia

Attribute	Ranking
Work in teams of ethnic and cultural diversity	4.7
Appreciate other cultures	4.6
Practice engineering in global context	4.5
Communicate across cultures	4.3
View as citizens of the world	4.2
Understand connectedness of the world; global economy	4.1
Understand cultural differences relative to engineering tasks	4.1
Deal with ethical issues	4.1
Understand cultural issues on product design	3.7
Speak at conversational level	3.5
Exposure to global supply chains, intellectual property, etc.	3.3
Familiar with history, government, economics	3.3
Speak at a technical level	3.1

Table 5. Ranking of Attributes by Industry

Attribute	Ranking
Communicate across cultures	4.5
Appreciate other cultures	4.5
Work in teams of ethnic and cultural diversity	4.4
Deal with ethical issues	4.2
Practice engineering in global context	3.9
Speak at conversational level	3.9
Understand cultural issues on product design	3.9
View as citizens of the world	3.9
Speak at a technical level	3.6
Exposure to global supply chains, intellectual property, etc.	3.6
Understand connectedness of the world; global economy	3.6
Understand cultural differences relative to engineering tasks	3.5
Familiar with history, government, economics	2.5

Table 6. Sum of Rankings

Attribute	Ranking Sum
Appreciate other cultures	9.1
Work in teams of ethnic and cultural diversity	9.1
Communicate across cultures	8.8
Practice engineering in global context	8.4
Deal with ethical issues	8.3
View as citizens of the world	8.0
Understand connectedness of the world; global economy	7.7
Understand cultural issues on product design	7.7
Understand cultural differences relative to engineering tasks	7.6
Speak at conversational level	7.4
Exposure to global supply chains, intellectual property, etc.	6.9
Speak at a technical level	6.7
Familiar with history, government, economics	5.8

Based on a sum of the rankings, the five most important attributes of global competence are that engineering graduates,

1. Can appreciate other cultures.
2. Are proficient working in or directing a team of ethnic and cultural diversity.
3. Are able to communicate across cultures.

4. Have had a chance to practice engineering in a global context, whether through an international internship, a service-learning opportunity, a virtual global engineering project or some other form of experience.
5. Can effectively deal with ethical issues arising from cultural or national differences.

We note that 12 of the 13 attributes were ranked as "Desirable" (corresponding to a score of 3.0) or higher. We also note that industry respondents indicated the importance of global competence for engineering graduates to be between "highly desirable" and "essential."

Caveats and Comments

A number of respondents included comments. Both groups were asked whether any aspects of global competence had been left out. Responses to this question included:

"…Live in another culture prior to graduation. Have the ability to learn from people of a different culture."

"Have confidence in their ability to live abroad."

"Include a question about the need to read books by foreign authors."

"Being from the most powerful country in the world, our students need to learn to treat others as equals who can enrich our work and our life."

"Students need to be curious as a character trait."

"Flexibility to switch to different cultures on a daily basis (today Tokyo, tomorrow Berlin, etc.)"

"Understand what is like to live in a foreign country. More and more we are asking Americans to live abroad. The decision-making process for this lifestyle change can be daunting."

"There needs to be an international experience, preferably one that is immersive."

"Competence in global communication tools."

Other comments from academia included:

"It is crucial to integrate courses on the global economy or cross-cultural differences and foreign languages into the engineering curriculum and provide internships abroad related to the students' major courses."

"I believe that to reach the highest/deepest level of cross-cultural competence with a specific second culture it is essential to speak the host language at a conversational level."

Other comments from industry were:

"[The importance of global competence] is highly dependent on the particular job. For some it may be a 2 and for others it may be a 5. But, in general it's between a 3 and a 4."

"When working in a particular country, it is indeed likely that engineers from another country will be working with nationals. If the nationals work for the same company, they can assist with cultural and language issues. But if there are no nationals to assist, or as business

interactions go to higher levels, it becomes more essential that individuals be knowledgeable of the culture and business environment."

"[Dimensions] like 10 and 11 are very important. Cultural issues are one part of doing business globally but I've experienced many difficult issues that have come from a lack of understanding (on both sides) of how engineering or processes are done in different parts of the world. Some things that may seem trivial to us are very difficult or different in other parts of the world and this can cause miscommunication, design issues, slow-down in implementation schedules as well as quality issues."

"A globally competent engineer requires an open mind and a sensitivity to the differences and complexities of other cultures. Due to the magnitude of the problem engineers should focus on one major country/culture or one major region."

Application

By defining global competence more precisely, engineering colleges can focus more specifically on the attributes they are trying to develop. Furthermore, some of these attributes could conceivably be developed without students traveling abroad. For example, the attribute, "Engineering graduates are proficient working in or directing a team of ethnic and cultural diversity," could be developed a number of ways, such as through a collaborative design experience, that would not have to involve travel. This is important since many study abroad programs do not scale easily, and it is not yet clear for many institutions how to provide an international experience for a large fraction of engineering students.

Summary

This paper has addressed two main questions related to global engineering education: "What does it mean for students to have global competence?" and, "What are the most important attributes of global competence?" In answer to the first question, we proposed and explained 13 separate dimensions of global competence. To answer the second question, we presented survey results from engineering educators and leaders in industry regarding the relative importance of these dimensions. Survey results were relatively consistent across respondents from academia and industry. From the survey, the five most important attributes were found to be that engineering graduates 1--Can appreciate other cultures; 2—Are proficient working in or directing a team of ethnic and cultural diversity; 3--Are able to communicate across cultures; 4--Have had a chance to practice engineering in a global context; and 5--Can effectively deal with ethical issues arising from cultural or national differences. Industry respondents also indicated the importance of global competence for engineering graduates to be between "highly desirable" and "essential."

By understanding better the various dimensions of global competence (and the relative importance of those dimensions), universities can design learning activities to develop competence in these attributes.

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