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Identification and Validation of a Set of Global Competencies for Engineering Students*

AARON G. BALL[1], HOLT ZAUGG[2], RANDALL DAVIES[2], ISAKU TATEISHI[2], ALAN R. PARKINSON[1], C. GREG JENSEN[1] and SPENCER P. MAGLEBY[1]
[1] Department of Mechanical Engineering, Brigham Young University, 435 CTB, Provo, UT, 84602, USA. E-mail: aaronball@byu.net, parkinson@byu.edu, cjensen@byu.edu, magleby@byu.edu
[2] Department of Instructional Psychology & Technology, Brigham Young University, 120 MCKB, Provo, UT, 84602, USA. E-mail: zaugg@gmail.com, randy.davies@byu.edu, isaku80@gmail.com

The 'flattening of the world', using Thomas Friedman's phraseology, is driving corporations to increasingly use collaborative engineering processes and global teams to operate on a global scale. Globalization of the traditional university engineering curriculum is necessary to help students prepare to work in a global environment. More research is needed to identify, aggregate, and validate a comprehensive set of global competencies. The purpose of this research was to identify and validate a comprehensive set of global competencies for engineering students. A review of the literature was first conducted from which numerous global competencies were identified. From this list of competencies, a set of global competencies with an associated conceptual model was developed to group the competencies by contextual topics. Two surveys were then developed and distributed separately to academic and industry professionals to obtain a critique of the importance and comprehensiveness of the global competencies that were identified. From this research a comprehensive set of 23 global competencies was identified and arranged within five broad categories. The 23 competencies were validated by two professional groups who rated each of the competencies based on their importance. Not all of the competencies were considered to have equal importance, but each was considered to be at least somewhat important; preference was typically placed on dispositional-based global competencies. Academic and industry experts largely confirmed that it was important for engineering students to develop these global competencies.

Keywords: global; intercultural; cross-cultural; competence; engineering education; global engineering

1. Introduction

As industry and world markets become more integrated internationally, there is a growing need for students to enter the workforce with global, cross-cultural skills and experiences. Educational opportunities designed to enable students to develop cross-cultural skills and gain global experiences have traditionally come through participation in study abroad programs, international internships, or combined degree programs sponsored by international university partnerships [1, 2].

These educational programs are typically founded on the central principle that the best cultural training results from immersing the student in an international experience. However, these types of experience vary with the extent to which students are exposed to other cultures. Programs range in length from only a few weeks to several months, and there are considerable differences in terms of what attitudes, skills, and knowledge students gain in the process. In fact, expert opinion is still divided on what it means for an individual to have obtained global competence [3–5]. Although previous research contributes to the breadth and depth of the understanding of cultural and global interactions that form the basis of global competence, there remains a lack of a descriptive, comprehensive, and consolidated set of statements describing global competence that has been validated by experts. Such a set of competencies is critical because it forms the foundation upon which academic institutions can create and assess the effectiveness of student engineering programs that are designed to help students develop global competence.

Although set in a mechanical engineering context, the purpose of this research was to outline a comprehensive set of competencies that describes what it means for an engineer (regardless of discipline) to be globally competent. To do this a review of the literature was conducted to identify elements that comprise global competence. Using the competencies that were identified, a set of global competencies was compiled along with a conceptual framework describing the relationships among the competencies. This set of competencies was validated by engineering academics and industry experts using an online survey designed to determine which competencies were most important.

2. Identification and categorization of global competencies

Defining, teaching, and assessing global competence is challenging for several reasons. Aspects of global competence (e.g., culture, language, relation-

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ships, etc.) are in a constant state of change. As cultural interactions increase, the shared values, mores, and beliefs that constitute culture are blended and altered. Meanings and understandings of terms in one culture do not always transfer to another culture. In addition, an individual must know and understand his or her own culture before they can compare and contrast it with another. This requires that the individual maintains a high level of cultural self-assessment and self-awareness. Despite these obstacles, experts often discuss the issue of global competence, the need for it, and what it means to possess global competence.

A review of the literature was conducted from which numerous global competencies were identified. Initial research of the literature examined 46 papers in 31 journals and five conference proceedings published within the last decade. Sources were picked based on their focus on international education, engineering education, or a combination of the two. Of these 46 papers, five were considered as seminal because of the extent to which they either examined international education in general, or investigated international engineering education in particular [3–7]. The intent of this literature review was to agglomerate global competencies that had been identified in previous research, yet remained fragmented throughout the literature.

Using these articles identified in the literature, key phrases (or statements) describing aspects of global competence were extracted by a team of three graduate research assistants. More than 100 descriptors of global competence (not all of which were unique) were identified and it became necessary to condense and categorize the list. The process for categorizing the competencies was as follows: First, similar competencies that had been mentioned by different authors using different terms were merged into one competency. Second, each researcher independently categorized the global competencies into categories and sub-categories. Next, the categorizations were reviewed among researchers and the discrepancies in terminologies were resolved. The number of categories was further reduced through an open debate and voting process until five broad categories remained.

The categorization process was completed when consensus was reached among the researchers that the list had been sufficiently condensed and defined such that the resulting categorizations were readily comprehendible, and that adequate preservation of the elements describing global competence had been maintained. The resulting categories of global competencies were re-worded so as to describe what a student would need to explain, describe, or demonstrate in order to be considered proficient in that area of global competence. The five categorical topics comprising global competence are listed below.

1. Cross-cultural communication
2. Cross-cultural dispositions
3. World knowledge
4. Cross-cultural teams
5. Engineering specific cross-cultural competencies.

3. Description of the global competencies

Each of the five categories that constitute global competence listed in the previous section is composed of specific knowledge, skills, and attitudes. These specific capabilities are directly related to those that were identified in the literature. Taken together, the global competencies support each of the global competency categories, respectively. A description of each of the five categories is provided by presenting the global competencies within each category, briefly describing their meanings, and providing related references to global competencies identified in the literature.

3.1 Cross-cultural communication

The student demonstrates knowledge and ability to communicate (speak, read, write, and listen) using a second language and cultural communication rules, while positively representing their own culture, people, company, etc.

3.1.1 Second language

The student demonstrates the knowledge and ability to communicate (speak, read, write, and listen) using a second language. This competency is based on competencies identified in the literature related to second language ability. Included is the ability to understand the mechanics and structure of a foreign language and the reflection of culture found in language. Further, this ability includes communicating through written and spoken forms of the second language [1, 6–11].

3.1.2 Cultural communication rules

The student demonstrates the knowledge and ability to appropriately apply cultural communication rules when communicating with people from different countries. Cultural communication rules describe general guiding practices for interacting with individuals from another culture by appropriately applying cultural framework principles identified by various researchers such as Hofsteade, Schwartz, Kluckhohn and Strodtbeck, House, Hall, and Trompenaars and Hampden-Turner [12]. These principles have application in both verbal and non-verbal communication. In addition, this com-

petency addresses the ability to communicate in different social contexts through proper word choice, use of idioms and humor, manner of speech, and appropriate body language [13–18].

3.1.3 Interpersonal representation

The student demonstrates the ability to positively represent their own culture, people, company, product, etc. in a foreign culture. An individual with this ability understands that their actions affect a broad range of relationships. From making good first impressions, to long term ethical actions and positive representations of self, team, company, and country, this competency captures knowledge, skills, and attitudes related to the importance and principles of interpersonal representation [19–23].

3.1.4 Communication technologies

The student describes the availability and appropriate use of collaboration technologies in cross-cultural interactions. Numerous technologies are available that provide synchronous and asynchronous worldwide communication possible. The multidimensional spectrum of technologies varies in the extent to which media richness is present, and the extent to which the communication is synchronous. Further, certain types of communication are better handled with a certain technology. This competency is related to using and making judgments regarding the use of collaboration technologies [24–26].

3.2 Cross-cultural dispositions

The student develops cross-cultural attitudes and beliefs (e.g. cultural appreciation, openness, and flexibility; a sense of cultural equality and global citizenship; a desire understand and explore other cultures).

3.2.1 Global citizenship

The student demonstrates a desire to work with people from different countries to solve cross-cultural or global problems. It is becoming more readily apparent that the difficulties faced by one nation or culture are inextricably intertwined with and impact the well-being of other global nations and cultures [11]. An individual that demonstrates global citizenship recognizes the interconnectedness of the world in which he lives. He recognizes that the challenges facing citizens of the world which do now and will yet exist can only be solved through global collaboration. Further, he demonstrates an interest in participating in efforts to address these global challenges [5, 8].

3.2.2 Global exploration

The student demonstrates a desire to learn about different cultures, world events, and social issues of the world. An individual that lacks an interest in other cultures and the greater world in which he lives has little impetus to understand or become familiar with foreign peoples, customs, and traditions. An interest in learning about foreign cultures, events, and issues is an attitudinal foundation that leads an individual to proactively seek to participate in global or intercultural exchanges. It also leads the individual to strive to ensure that these global or intercultural interactions are successful and positive experiences [6].

3.2.3 Cultural equality

The student views all cultures without prejudice, stereotypes, and discrimination, and interacts with people from any culture as equals in social status (i.e. without ethnocentrism). An attitude of cultural equality enables individuals to see beyond and withhold judgment about the most notable differences that exist between peoples of different cultures. This capability enables individuals to become acquainted with and understand one another on a personal level—a level of understanding and familiarity that comprehends individual uniqueness within the culture of which the person is a member. Further, the capability provides the relational foundation upon which trust can be established and meaningful collaborations can occur [15, 27].

3.2.4 Cultural flexibility

The student tolerates and flexibly deals with cultural differences without emotionally disturbing others. It is highly unlikely that individuals can find agreement upon all cultural differences, but rather it is almost certain that there will be elements that differ among cultures about which there is disagreement. It is in these situations that it is necessary for those involved to be tolerant and flexible such that differences in culture can be negotiated or addressed in both a civil and emotionally restrained manner. The knowledge related to this ability and its application is included in this competency [27, 28].

3.2.5 Cultural appreciation

The student appreciates and respects cultural differences (e.g., language, social rules, political systems, arts, music, etc.). There are always differences that can be found among cultures. These differences may be manifest in language, politics, music, the arts, etc. One who demonstrates this capability recognizes the advantage that differences of perspective provide in solving problems and in collaborating as a team. Showing appreciation and respect for cultural differences builds a framework that facilitates global collaboration [7, 27].

3.2.6 Cultural openness

The student evaluates cultural differences from a perspective different from their own cultural norms and takes advantage of the differences when appropriate. Different from cultural appreciation, this competency addresses the attitude and ability to compare and evaluate cultures. A person with this capability recognizes that elements of his own culture have been influenced and likely adopted from those of another culture. In order to demonstrate cultural openness, not only must ethnocentric tendencies be overcome, but also a willingness to learn about and personally adopt elements of another culture must be developed. This disposition leads an individual to not only interact well with those of another culture, but enables him or her to recognize that much can be learned from those of another culture and causes him or her to seek to learn from and adopt advantageous cultural practices [4, 27].

3.3 World knowledge

The student demonstrates an understanding of the world in terms of values, geography, religion, language, culture, political and economic systems, including current and historical world events.

3.3.1 General knowledge

The student demonstrates a general understanding of global history, events, public policy, politics, world organizations, geography, dominant religions, etc. One demonstrating this competency not only has a general understanding of global facts, but understands the need to be aware of and knowledgeable about global topics and trends. An individual with this competency will recognize the influence that historical and current events, policies, organizations, etc. have and will have on him personally and his surrounding society [5, 7, 29].

3.3.2 World Cultures

The student identifies, compares, and contrasts beliefs, values, perspectives, practices, and products of their own culture with that of others. Beyond general global knowledge and an understanding of its local impact, an individual with this capability also recognizes the differences and similarities among world cultures. A person with this ability further can make predictions about the behavior and preferences of an individual based upon that person's culture. Although such an individual can make reasonable predictions, they understand that cultural level factors do not supplant personal preferences, and expect to refine their understanding of another's person according to their individual behavior, experiences, and preferences [27, 30].

3.3.3 Global interrelations

The student understands concepts of sustainability and globalization. Related to the competency described by global citizenship, this learning outcome emphasizes the topic of sustainability in a globalized world. Individuals with this ability recognize the interconnectedness of the world and its local, personal, and professional implications. They further understand that this trend will continue to influence the societies in which they live. As members of a global, inter-related community, persons with this ability understand sustainability in a global context and seek to appropriately apply principles of sustainability [7, 29, 31].

3.4 Cross-cultural teams

The student demonstrates the ability to work in an international team toward a common goal using strategies that encompass the team's cultural diversity.

3.4.1 Team leadership

The student demonstrates the leadership skills needed to guide an ethnically and culturally diverse team toward a common goal. An individual with this attribute has developed the skills to guide the completion of a project by a team composed of members from different nations or cultures. Such a person can build a cohesive team with a common understanding of leadership and team roles, vision, purpose, and goals. In addition, an individual with this capacity understands how cultural background influences the perception of the proper role, responsibilities, and style of team leadership [7, 32].

3.4.2 Team processes

The student understands the influence of culture on structuring team processes, developing team objectives, establishing team rules, building trust among team members, and work values and practices. An understanding of the way in which teams operate, make decisions, approach tasks, etc., is one of the abilities encapsulated by this competency. An individual that has developed this ability will also recognize that the way in which people from different cultures approach and understand work can differ and that these differences need to be understood, particularly in an interdependent team environment. Also, an individual with this capability will both recognize the influence of culture on other team principles such as the development and understanding of objectives, rules, and trust, and also work to adopt adaptations to these principles that meet the needs of the team [3, 24, 33].

3.4.3 Conflict resolution

The student identifies team conflicts arising from ethnic differences and implements culturally sensitive strategies to resolve these conflicts. As noted by Halverson and Tirmizi, a team progresses through several stages in its lifetime, including a 'storming' stage where conflict is high [34]. Resolving conflict among team members is important for any team. However, this competency is focused on resolving conflicts resulting primarily from cultural or ethnic differences. An individual with this ability understands and anticipates potential sources of conflict. As those differences are manifested and conflict occurs, he can act tactfully to resolve team member differences and enable the team to improve its working relationship [3, 32, 34, 35].

3.4.4 Cross-cultural team experience

The student demonstrates the ability to collaborate effectively with cross-cultural team members to accomplish a common goal. The literature suggests that one of the best ways to develop global team collaboration skills is through actual experience working in a global team environment. An individual demonstrates this ability through participation in a real collaborative project that involves persons from another culture and country. He or she demonstrates the ability to recognize and manage global team dynamics in an environment where his or her teammates may or may not be physically present [15, 36, 37].

3.5 Engineering specific cross-cultural competencies

The student demonstrates an understanding of the influence of culture on the engineering profession, engineering practices, product design, and cross-cultural engineering collaboration.

3.5.1 Cross-cultural engineering attitudes

The student appreciates, respects, and values the engineering contributions of another culture. As an engineering specific manifestation of the more generalized form of the Cross-cultural Appreciation competency, an individual who has developed this ability is appreciative and respectful of the engineering work performed by those of another culture. He or she values the insight that can be provided by global colleagues in an engineering environment [4].

3.5.2 Cross-cultural engineering interaction

The student demonstrates the ability to successfully interact with engineers (or engineering students) from another culture. Representing an engineering specific manifestation akin to the Cross-cultural Team Experience competency, individuals who have demonstrated this ability can successfully communicate about technical engineering topics and documents. The individual with this ability understands how to use PLM tools to collaborate regarding engineering product design and development processes. In addition, such an individual has learned how to operate and successfully manage and complete a project in a global, distributed team environment [1, 32, 37].

3.5.3 Cultural engineering skills and practices

The student understands how engineering skills and practices differ among the cultures of the world. An individual that has developed this capability will understand that although engineering principles—principles based in the natural sciences—should not vary from culture to culture, engineering processes, skills, and practices may have wide variation throughout the world. An individual with this ability will understand that the problem solving approach and the way in which engineering tasks are defined and carried out are subject to cultural values. In addition, the standards used and the ethical practices followed may vary greatly according to national or cultural influences [4, 38].

3.5.4 Global engineering occupations

The student understands the cultural and business context surrounding occupations in global engineering. Included in this competency is an understanding of the role of engineering work, and the cultural, or social, status of engineering professionals among different cultures. An individual who has developed this competency has an understanding of general principles of global business, collaborative engineering, and global intellectual property issues. Also, this individual will understand how globalization is influencing the engineering profession for different nations and cultures [39–42].

3.5.5 Culture-centered product design

The student demonstrates an understanding of how culture influences product design. An individual who has developed this capability understands that some products are more culturally sensitive than others, and can identify examples of products that are both culturally insensitive and culturally sensitive. For culturally sensitive products, he also understands the extent to which culture can influence the evaluation and eventual adoption of a product or service. In addition, an individual who has developed this competency has an understanding of the process for developing a globalized product and localizing it for regional or local markets [43–45].

4. Hierarchical global competence model

During the categorization process described in the previous section, a framework for describing and understanding the global competencies was identified. The model provides insight into how each of the global competencies is contextually related. As this model is beneficial to understanding global competence, the model is described in this section (see Fig. 1).

Competencies range from general to specific. This is represented in the model by three levels: general, organizational, and disciplinary (i.e. discipline specific). For example, some professional competencies are general in nature. Communicating respectfully and clearly often influences the effectiveness of an individual's personal relationships. Other competencies are situated within a specific organizational setting. Knowing the best ways to both work on a team and to communicate with clients and colleagues are important. Still other competencies are discipline specific. In an engineering setting, communicating engineering design details, performing analyses, and solving problems are each essential engineering specific competencies. Introducing elements of cultural diversity can alter the nature of the competencies needed to be successful at each level.

Several of the competencies needed by students preparing to work in a globalized engineering environment will be either influenced or driven by culture. As noted in Fig. 1, these competencies appear in the region described as 'Cultural Interaction' and have a presence in all levels. The model is constructed in this manner to indicate that certain competencies are unaffected by culture. For example, an understanding of physical phenomena and governing principles in engineering is exclusive of cultural effects. However, communication skills, or working with others to accomplish goals can easily be influenced by cultural effects.

Several caveats that provide greater information about the model should be noted. First, there is nothing sacrosanct about the levels that were used to represent the specificity of competencies in this model. Other names, or more or fewer levels, might be just as appropriate. Second, the levels do not represent clearly defined boundaries. Rather, it is likely that more of a gradation exists moving from a completely general level to a highly disciplinary specific level. In addition, it should be noted that competencies in more general categories may have more specific manifestations in more specialized levels. For example, the ability to communicate could be described and assessed on multiple levels: general or conversational, professional, and technical.

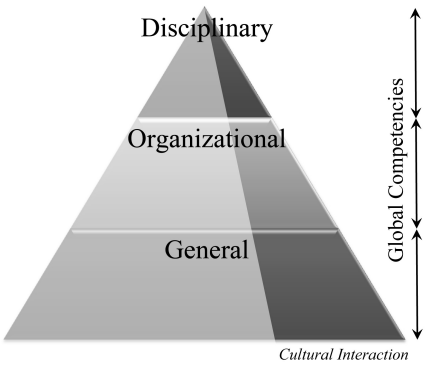

Fig. 1. Hierarchical model describing both the breadth of global competencies from general to specific levels and the interaction of global competencies with culture.

The set of identified global competencies are predominantly found within the region labeled 'cultural interaction', and are further described by this model in the following way: Global competencies found in the Cross-Cultural Communication, Cross-Cultural Dispositions, and World Knowledge categories generally represent general level competencies. However, more specific manifestations of those competencies can be found within the higher levels of the model. The competencies within the Cross-Cultural Teams category more appropriately fit in the organizational level. Lastly, the Engineering Specific Cross-Cultural Competencies, as apparent through the title, fit most appropriately in the disciplinary level of the model. In summary, the model provides an appropriate way to categorize and understand the relationships among the various global competencies.

5. Validation of global competencies

In an effort to validate the above set of global competencies resulting from the literature review and categorization process, a survey instrument was developed and administered to industry and academic professionals. To ensure consistency in the scope and context of this study, emphasis was placed on obtaining feedback from the mechanical engineering community. Despite this narrowed focus, the validation results are likely applicable for all engineering students. However, it is noted that a broadened validation effort would improve the strength of these findings across engineering disciplines. In this section, a brief description of the survey instrument, a demographic profile of each of the response groups, and a presentation of the results of the two surveys is provided.

5.1 Description of survey instruments

Two electronic surveys—one for each response group—were developed and administered using the Qualtrics online survey program [46]. The two

surveys were very similar, with primary differences resulting from different demographics questions.

The first survey was developed for administration to a group of working mechanical engineering professionals. The survey consisted of 38 questions in four sections. Each respondent was prompted to provide: acknowledgement of informed consent to participate in the study, demographic information regarding their employment, demographic information about the company in which they were currently employed, and an evaluation of the set of global competencies identified in this study. Using a Likert-type response scale ranging from 'Unimportant' to 'Very Important', respondents were directed to evaluate how important each of the global competencies was when considering the global competence of a mechanical engineer at their company. Respondents were asked to provide any additional competencies not identified in the survey.

The second survey was similar to the first, but was developed for administration to a group of academic professionals who participate in the Partners for the Advancement of Collaborative Engineering Education (PACE) program. PACE is an industry sponsored organization that promotes the student development of engineering product lifecycle management (PLM) skills learned through a global collaborative environment [47]. The survey consisted of 47 questions in five sections. Respondents were prompted to provide: acknowledgement of informed consent to participate in the study, employment information, global demographics, an evaluation of the set of global competencies, and a self assessment of global competency. Using the same Likert-type response scale as in the first survey, respondents were directed to evaluate how important each of the global competencies was when considering the global competence of a student preparing to work as an engineer in a global workforce. Respondents were also asked to provide any additional competencies not identified in the survey.

5.2 Response group demographics

For the industry professional group, the survey was sent to individuals located in 30 states in the USA and ten additional countries worldwide. Professionals included in the survey group were identified and drawn from a collection of industry contacts from the professional networks of the researchers involved in this study. A total of 106 companies (e.g. Boeing, Caterpillar, Ford, General Motors, Honeywell, Pratt & Whitney, and Siemens AG) were represented in the sample group, including 390 individuals. Only 37 individuals responded for a response rate of 9.5%. Thirty of the respondents (82%) were located within the USA. The remaining individuals (18%) were from five additional countries (Canada, Australia, Japan, Korea, Brazil). Most of the respondents (94%) had been employed in industry for over 10 years, with 53% of the sample holding management or director positions. Most of the respondents (70%) worked at companies employing over 10 000 people, with 49% of respondents indicating that their company had annual revenues of over 10 billion US dollars. Additionally, 49% of respondents indicated that more than half of their company's business was for international markets.

For the academic professional group, the survey was electronically administered to 439 PACE affiliated individuals located at one of more than 50 universities worldwide. With its founding roots in and continuing emphasis focused on the automotive industry, PACE is composed of professionals predominantly affiliated with the mechanical engineering, manufacturing engineering, or industrial design and engineering disciplines. The response rate was 9.6% (42 individuals), with 43% of the respondents located within the USA. The remaining 57% of respondents were located in seven additional countries (Mexico, Canada, India, Germany, Korea, China, Australia). Most of the respondents (57%) had been employed in higher education for over 10 years. The majority (69%) of respondents held full-time faculty status. Most of the respondents (95%) were employed in engineering departments, of which 45% were in mechanical engineering departments. Almost half (48%) of the respondents had been involved in teaching or supervising global curricular activities for more than four years, with 36% of respondents having directed or facilitated extracurricular global activities. Additionally, 29% of respondents had been involved in researching topics related to global or cross-cultural issues for more than four years. A large majority of the respondents (88%) provided a self-rating of good, very good, or excellent when describing their personal global knowledge, skills, and abilities.

5.3 Survey results

The results from the two surveys regarding the importance of specific global competencies were collected and analyzed. Responses indicating how important each of the 23 identified competencies were when evaluating an individual's global competence were aggregated and are reported in order of importance in Table 1. Each competency is listed in this table, along with its associated competency grouping (i.e. COMM-Communication, DISP-Dispositions, WRLD-World Knowledge, TEAM-Teamwork, and ENGR-Engineering Specific). The industry and academic group means are provided as

well as overall means and standard deviations for each competency. The 1 to 5 point scale corresponds to the 5 point Likert-type response scale used in the survey. A rating of 1 indicated that the competency was 'Unimportant'; 2—'Of little importance'; 3—'Moderately important'; 4—'Important'; and 5—'Very important'. An asterisk next to the overall mean for specific competencies indicates where there was a significant difference in the responses between the two groups that were surveyed.

Table 1. Validation of global competencies by academic and industry respondents ordered by overall importance

Competency group	Global competency	Response group	Group means	Overall mean	Overall std dev.
	Very Important				
DISP	Appreciate and respect cultural differences.	Industry Academia	4.5 4.7	4.6	0.6
DISP	Practice tolerance and flexibility when involved in intercultural interactions.	Industry Academia	4.3 4.8	4.6*	0.7
TEAM	Collaborate and work towards a common goal as a team member on a multicultural team.	Industry Academia	4.4 4.6	4.5	0.7
	Important				
DISP	Practice cultural equality by eliminating personal cultural prejudices, stereotypes, and discriminatory practices.	Industry Academia	4.3 4.6	4.4*	0.7
COMM	Use collaboration technologies in intercultural interactions.	Industry Academia	4.4 4.1	4.2	0.9
TEAM	Identify, resolve, and minimize conflicts resulting from cultural differences.	Industry Academia	3.8 4.5	4.2*	0.8
TEAM	Develop multicultural team leadership skills.	Industry Academia	3.9 4.4	4.2*	0.8
ENGR	Interact with engineering students (or engineers) from a culture different than own.	Industry Academia	4.0 4.2	4.1	0.9
ENGR	Understand and respect engineering practices and contributions that are foreign.	Industry Academia	3.8 4.4	4.1*	0.8
TEAM	Describe how culture influences team processes.	Industry Academia	3.9 4.1	4.1	0.8
WRLD	Understand concepts and principles of sustainability and globalization.	Industry Academia	3.7 4.3	4.0*	0.9
COMM	Apply principles of intercultural communication.	Industry Academia	3.8 4.3	4.0*	0.8
DISP	Develop a desire to interact with people from different countries to solve global problems.	Industry Academia	3.8 4.1	4.0	0.8
ENGR	Describe how culture influences engineering product design.	Industry Academia	3.6 4.2	3.9*	1.0
ENGR	Explain basic principles of global businesses.	Industry Academia	4.0 3.8	3.9	0.8
WRLD	Understand and compare world cultures.	Industry Academia	3.6 4.1	3.9*	0.9
ENGR	Explain how culture influences engineering design processes, standards, problem solving, and manufacturing processes.	Industry Academia	3.7 3.8	3.8	0.9
ENGR	Describe how culture affects the perception of engineering work and the engineering profession throughout the world.	Industry Academia	3.6 3.7	3.7	0.9
DISP	Objectively evaluate and adopt advantageous cultural practices and values.	Industry Academia	3.2 4.0	3.6*	0.9
DISP	Develop a desire to learn about different world cultures, events, and social issues.	Industry Academia	3.2 3.9	3.6*	0.9
	Somewhat Important				
COMM	Represent own culture, social group, company, nation, etc., in a foreign culture.	Industry Academia	3.2 3.7	3.5*	1.0
COMM	Communicate in a second language.	Industry Academia	3.1 3.7	3.4*	1.1
WRLD	Increased general knowledge of global history, events, public policy, politics, world organizations, geography, religions, etc.	Industry Academia	3.1 3.6	3.4*	0.9

* Differences in means between the two groups were statistically significant based on t-test results at the 95% confidence level.

6. Discussion of survey results

In general respondents indicated that all of the competencies were at least somewhat important. However, academics tended to place higher importance on each of the competencies than industry experts did. Many of these differences were statistically significant. As indicated in Table 1, significant differences for 14 of the 23 competencies were found between the two response groups. In each of these cases, academia considered the competencies to be of higher importance than did industry respondents. Still, there was a strong correlation between the ratings of the two groups ($r = 0.75$).

These results suggest that the large majority of identified global competencies are important, but that they are not all equally important. Only three of the competencies were considered to be 'very important'. The most important competencies involve attitudes and abilities focused on working effectively with individuals in a culturally diverse team setting. Dispositions regarding cultural respect, tolerance, flexibility, and equality were seen as being most important. The ability to work collaboratively as a member of a multicultural team, to resolve cross-cultural conflicts, and to use collaboration technologies in intercultural interactions were also quite important. In contrast, it was found that knowing a second language, representing your culture or company, and developing a desire to learn about world cultures were considered only somewhat important.

The five competencies rated most important by the industry group (listed in order of importance) were: appreciate and respect cultural differences, collaborate and work on a multicultural team, use collaboration technologies in intercultural interactions, practice tolerance and flexibility, and practice cultural equality. Academic respondents considered the five most important competencies to be: practice tolerance and flexibility when involved in intercultural interactions, appreciate and respect cultural differences, collaborate and work towards a common goal as a team member on a multicultural team, practice cultural equality, and identify, resolve, and minimize conflicts resulting from cultural differences, respectively. With the exception of the ability to use collaboration technologies in intercultural interactions (ranked as only thirteenth by academics in terms of importance), the most important competencies identified by academics were similar to those identified as most important by industry respondents. This seems to indicate that positive cross-cultural attitudes and practical collaborative personal and teamwork skills are of paramount importance.

6.1 Differences by geographic location

Geographic influences tended to significantly affect several response patterns. Respondents from the US considered communicating in a second language to be only 'Moderately important' whereas respondents from all other countries tended to rate this competency as 'Very important' ($\chi^2(4) = 22.2$, $p < 0.001$, $ES\ V = 0.53$). This strong disparity in response patterns is likely explained by the fact that English is widely accepted as the international language of engineering. Native English speakers would probably tend to consider communicating in a language other than English to be of less importance than non-English speakers considering it to be very important to learn to communicate in English, a second language. Also, USA respondents tended to rate the desire to learn about different world cultures as only 'Moderately important' whereas all other respondents provided a rating of 'Important' ($\chi^2(3) = 9.0$, $p < 0.029$, $ES\ V = 0.34$). The USA has for many years been a dominant market in the world economy. It is possible that those living in the US have not found it to be as critical to understand the cultures of countries in which they have little interaction compared with those in other countries who have significant interaction with individuals within the USA.

Several other significant insights were also noted in the results that appear to be location dependent. Comparing responses of professionals in the USA with those in all other countries, USA respondents rated the importance of using collaboration technologies in intercultural interactions primarily as 'Very important' as compared with a rating of 'Important' by those in all other countries ($\chi^2(3) = 8.8$, $p = 0.033$, $ES\ V = 0.49$). This trend might be explained by the culture of the USA in which many individuals are early adopters of technology and are more comfortable than those in other countries with communicating through technological methods that provide less immediacy, or social presence, than what is afforded in face to face interactions. Similarly, USA respondents rated practicing tolerance and flexibility when involved in intercultural interactions as 'Very important' whereas those in all other countries generally rated the competency as only 'Moderately important' ($\chi^2(2) = 8.8$, $p = 0.012$, $ES\ V = 0.49$). Perhaps there is greater emphasis placed on these attributes in the cultures of engineering companies located in the USA than in engineering companies located in other countries.

6.2 Differences based on the position of the respondent

A third interesting relationship was found in controlling response by job type. Managers (or Direc-

tors) considered using collaboration technologies in intercultural interaction to primarily be 'Very important' whereas all other job-types generally ranked the competency as 'Important' only ($\chi^2(3) = 15.1$, $p = 0.002$, $ES\ V = 0.64$). Managers and directors are heavily involved in collaborative tasks in business and engineering. Their perspective may be influenced by their own experience, or by their vision and understanding of trends related to collaborative engineering activities.

6.3 Differences based on international experience

Interestingly, no significant differences in academic responses were found when controlling for faculty status, department affiliation, and years involved global curricular activities. However, academicians who provided a self-rating of their own global competence of poor, fair, or good provided split ratings for collaborating and working towards a common goal on a multicultural team as either 'Important' or 'Very important' whereas those indicating a higher personal rating (very good or excellent), rated the competency as 'Very important ($\chi^2(2) = 8.6$, $p = 0.014$, $ES\ V = 0.45$). Academicians who provided a high self rating related to global competence may have more extensive first-hand experience in multicultural interactions than other academic respondents, leading them to recognize the challenges associated with these interactions and the importance of obtaining experience in this area. This same global competency was also influenced according to the number of countries in which the respondent had lived. Those who had lived in more than one country tended to indicate that collaborating as a team member on a multicultural team was 'Very important', whereas those who had not lived in more than one country tended to rate the competency as 'Important' only ($\chi^2(2) = 12.2$, $p = 0.002$, $ES\ V = 0.54$). This finding may be explained in a similar way to the previous finding in that increased personal experience in intercultural interactions may directly influence the extent to which interacting with those from another culture is perceived as important to developing global competence.

6.4 Additional competencies

An additional competency was suggested that was unique among the other competencies that were rated by respondents. It was based upon the idea of maintaining long term international networks. Although one of the dispositional competencies focuses on developing a desire to interact with people from different countries to solve global problems, no effort to maintain long term social or project networks was included in the set of global competencies.

7. Conclusions

In conclusion, the increasing globalization of the engineering environment is driving an increasingly important need for globalized university engineering curricula that prepares graduates to work in this global environment. Through a review and an analysis of the literature, over 100 global competencies were identified. Through a categorization process, a set of 23 global competencies was created, in five broad categories. Each of the five general competency categories and the 23 specific global competencies was described. A framework was also created and described that illustrated the relationship among the 23 competencies.

To provide further validation of the 23 competencies that were identified, two surveys were administered to academic and industry professionals worldwide. The respondents from each of these groups considered the large majority of the 23 global competencies to be important. Academic respondents tended to rate each of the competencies as more important than did industry, but there was strong agreement between the ratings provided by the two groups. Geographic influences tended to affect how respondents rated the importance of several of the competencies. Among the 23 competencies considered, the most important tended to be dispositional-based global competencies. The underlying need for developing global competencies seemed to center around the ability of a mechanical engineer to work collaboratively as a member of a multicultural team to accomplish a common task.

8. Future research

The identification of a comprehensive set of important global competencies marks an important first step in designing and implementing an effective curriculum that better prepares engineering students for a global work environment. However, several areas need to be researched further. First, methods of teaching important global competencies to engineering students must be further investigated, including identifying what kinds of activities help students develop global competence. In addition, a comparative evaluation of current global educational programs, such as engineering study abroad programs, international internships, and course-based collaborative team projects should be conducted to identify the extent to which the programs enable students to develop the identified global competencies.

Second, further exploration must be made to identify the optimum sequence of instructional activities that will maximize student development of global competence. A globalized engineering

curriculum will need to incorporate global competencies throughout the entire program since no one course will likely be able to (or should) provide opportunities for students to adequately develop each of the important competencies. There is a need to identify when and where specific global competencies should be emphasized. Also, since many of the global competencies are more general in nature, partnerships with other colleges within the university should be investigated as they may facilitate improved instruction of those competencies outside of engineering courses.

Finally, standardized methods of measuring the effectiveness of the instructional activities designed to help students develop global competencies must be designed and implemented. Best uses of assessment data to improve engineering programs and to assist students in developing global competence remain to be identified.

We encourage the engineering education community to actively participate in sharing their efforts for developing global instructional curricula and assessment tools designed to facilitate the development of important global competencies.

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Aaron G. Ball is a mechanical engineering MS candidate at the Ira A. Fulton College of Engineering and Technology at Brigham Young University. He is also concurrently an MBA candidate at the Marriott School of Management at Brigham Young University. He graduated summa cum laude with a BS mechanical engineering degree from Brigham Young University, Idaho. Aaron has previously worked in the automotive and aerospace industries. His current research is focused on identifying and validating global competencies for engineers and developing and evaluating educational programs designed to enable engineering students to develop global competence. He is a member of ASME.

Holt Zaugg is a doctoral candidate at Brigham Young University in the Educational Inquiry, Measurement and Evaluation program. His current research focuses on communication patterns of engineering students working on global, virtual teams and test item measurement analysis using Item Response Theory and Confirmatory Factor Analysis.

Randall S. Davies is currently an assistant professor of Instructional Psychology and Technology at Brigham Young University. His research involves program evaluation in educational settings with the general objective of understanding and improving the teaching and learning process. His research has a specific focus of evaluating technology integration, assessment policy, and educational practices.

Isaku Tateishi is a psychometrician/UX researcher at TestOut Corporation. He has published articles related to group creativity, communities of innovation, research technology, global distance education, and instructional design and development. He received his Ph.D. in Instructional Psychology and Technology from Brigham Young University.

Alan R. Parkinson is a professor of mechanical engineering and currently serves as dean of the Ira. A. Fulton College of Engineering and Technology at Brigham Young University. The college is home to 3300 students in 11 programs. Previous to his appointment as dean he was an associate dean from 2003 to 2005 and chair of Mechanical Engineering from 1995 to 2001. He received his Ph.D. and MS degrees from the University of Illinois, Urbana, and BS and MBA degrees from Brigham Young University. Dr. Parkinson's areas of research interest include design automation, optimization methods, robust design, and engineering education. He is currently conducting research on cross-cultural virtual engineering design teams. He is a co-author of a commercial optimization software package, called OptdesX, which has been used at companies and universities in the United States and Europe. In 2003, he received the Design Automation Award from the American Society of Mechanical Engineers for his work in robust design and design optimization. Dr. Parkinson was elected to Fellow status in the American Society of Mechanical Engineers in 2004.

Spencer P. Magleby is a Professor of Mechanical Engineering and Associate Dean in the Fulton College of Engineering and Technology at Brigham Young University. He came to BYU in 1989 after working in the aircraft industry, developing tools for advanced aircraft design and manufacture. Dr. Magleby received his Ph.D. from the University of Wisconsin where his research centered on design. He has pursued research in design tools and processes, team management, and new mechanism technologies. He teaches design and product development at the graduate and undergraduate level, and is interested in educational partnerships with industry, and international issues in design. As dean of undergraduate studies he has promoted and supported the expansion of international programs. He is an active member of ASME and ASEE.

C. Greg Jensen joined the faculty at Brigham Young University in 1983. He received both his BS and MS at BYU. In 1993 he completed his dissertation, 'Analysis and synthesis of multi-axis sculptured surface machining' at Purdue University. He is currently the director of the NSF IUCRC v-CAx site (a sub-site off the Center for e-Design), which is focused on the development of next generation multiuser collaborative cloud-based CAx tools and methods. Dr. Jensen was chosen as the first Fulton College Professorship of Global Engineering, a position he held from 2007 to 2009. Under the direction of Dr. Jensen, BYU's mechanical engineering students have participated in six PACE global collaborative design projects. From 2006 to 2010 he directed a PACE Project that spanned 19 time zones and involved 26 national and international schools in the modeling, analysis and manufacturing of four working Formula-1 type racecar. Dr. Jensen has also conducted research in Engineering Design and Modeling found in the specific areas of Computer Aided Geometric Design, Parametric CAx Modeling, and Multi-discipline CAD-centric Design Optimization. He is currently involved in the development of next generation CAx tools, curvature matched machining methods, parametrics and customization of CAx tools for industries such as Boeing, GM, Pratt & Whitney, ATK, Ford, Belcan, etc.