Assessing Global Competence and Teamology for Collaborative Engineering

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Abstract

There is a need to make measureable improvements to the global competency of engineering students that will enable them to work more effectively with overseas colleagues. However, there are few assessment tools that offer clear guidance on which types of global exposure (coursework, virtual collaboration, or education abroad) provide substantial benefit. Additionally, with the increasing reliance on teams to solve problems in both industry and academia, there is a need to ensure high-performance and inventiveness. This thesis addresses these two challenges by 1) developing a new assessment tool for gauging global competency and evaluating a commercially-available tool, and 2) validating and simplifying Wilde's teamology method for assembling better teams. The newly developed Global Competence Survey (GCS) is a quick and effective tool that is able to delineate between student groups based upon duration of education abroad. In its current form, the GCS works by assessing student knowledge of key facts about USA and Germany, and their ability to recognize cultural images. This first attempt shows statistically significant differences between domestic, three-month abroad, and year-long abroad students in these critical areas. Additionally, the teamology method was confirmed empirically by analyzing the performance of two-person global research teams assembled using traditional selection criteria. This analysis shows that teams with greater personality diversity exhibit far higher performance and stronger cohesion. When coupled with functional role requirements, teamology provides an opportunity to dramatically enhance the team performance and cohesion of an available talent pool.

Dedication

This thesis, and the toil it took to produce it, is dedicated to my wonderful family, who have supported me in so many ways and always encouraged my achievement. To my sisters Jennifer and Mary, who have both inspired and challenged me for as long as I can remember. Most especially to my late father, John, and my mother, Anne, who together taught my sisters and me to build our own monuments.

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Also, to my committee members, Scott Huxtable, Ph.D., and Chris Williams, Ph.D., for their critical support and feedback that have helped to strengthen this document and my grasp on this material. My sincere thanks to Steven Culver, Ph.D., of the Office of Academic Assessment, for his guidance in developing the Global Competence Survey, and keen interest in my success.

To my friend and mentor Joe Meredith, Ph.D., whose course on *Global Issues in Industrial Management* served as a primer for this thesis and whose guidance has made me a better engineer and person. Also, to my friend and mentor Professor Ken Harmon, whose boundless encouragement and timely wisdom helped me weather the storm of graduate studies. Also, to Gary Downey, Ph.D., for his course on *Engineering Cultures*, and Douglass J. Wilde, Ph.D, for his pioneering work with teamology, who have both inspired me and whose work served as a foundation for this thesis.

To my lab mates, Jesse and Amy, for much fun and serious learning over these past few years. I have enjoyed immensely getting to know you both and exploring our different paths together. And to the many patient reviewers of what became these chapters—your insightful critique made this document come together.

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Chapter 1

Introduction

The engineering profession is changing as the pace of technological development accelerates and engages larger and more culturally diverse teams to solve emerging challenges. As a result, engineering graduates are expected to possess intercultural skills that will enable their professional performance. Global competency is a much desired yet poorly defined level of proficiency that universities and employers seek in engineering graduates. At present, small numbers of engineering students are sent abroad and expected to return home with the ability to interact effectively with foreign colleagues.

Furthermore, it is increasingly likely that students will work as contributors on teams composed of individuals not only of different functional groups, but also members of different cultures collaborating across multiple time zones. Collaboration requires that students go beyond individual mastery of course subjects and presents a challenge both within an already crowded curriculum and financially-strained departments. This increasing focus on teaming also presents an opportunity to examine methods for enhancing team performance.

1.1 Problem Statement

Most studies until now have focused on developing or applying universal assessment tools to student groups in hopes of quantifying previously anecdotal evidence of student gains through study abroad. While this study utilizes one such tool, the recently developed Global Competence Aptitude Assessment, as a baseline, this study also makes the logical step of evaluating student gains in understanding relevant facts and grasping dominant cultural stereotypes for their home and a single host country. This appears to increase the resolution of the instrument, and also provides an indication that these students have made a significant transition in achieving competency in succeeding in both home and host countries.

The objective of this thesis is to evaluate the impact of two different study abroad programs on the global competency of engineering students, and to evaluate the teamology personality-based methodology for improving team outcomes.

1.2 Solution Outline

Many studies have attempted to show student progress in intercultural sensitivity using the Intercultural Development Inventory (IDI), a tool that historically has provided limited guidance on short-term excursions, which form the majority of study abroad experiences. This study will attempt to show the growth in engineering student global competency using the Global Competence Aptitude Assessment (GCAA) and through the shorter, country-focused Global Competence Survey (GCS).

As no single definition of global competency exists, the GCS was developed using key and measureable criteria from the literature on global competency. This research shows that study abroad has a significant impact on these measureable traits, and confirms anecdotal results from study abroad. The GCS includes key historical and current events questions, plus cultural questions derived from management texts. This approach used symmetric factual and cultural questions so that the study groups could be compared based on their understanding of their own and a host culture.

The GCS offers the benefit of determining student growth in a practical, quick, and inexpensive way, while focusing on evaluating real improvement in working with other cultures. In developing this targeted method, this study traded completeness for brevity to improve student response rates, while maintaining high resolution. By gaining intense exposure to a single country, this research shows that students who study abroad demonstrate skills that are critical to achieving global competence:

1. The ability to recognize and process non-native cultural cues
2. A greater understanding of their home country and culture

Additionally, the teamology method was evaluated for use in enhancing cross-cultural research teams. While teamology has been used to assemble high-performance teams at Stanford University for nearly twenty years, this method has as yet not been validated as an essential component of their success. By using the results of prior international teams designed for strong performance through traditional means, this study shows that teamology could have dramatically enhanced the effectiveness of even these teams, as measured by their performance and cohesion.

1.3 Thesis Organization

This thesis describes the experimental design and results of three separate tools intended to assess global competency or assemble teams better equipped for collaborative engineering. Specifically:

Chapter 2 reviews the intellectual underpinnings of this research project with an overview of how cultures differ, prior work in defining and assessing global competence, and methodologies from Stanford University for assembling intrinsically better performing teams.

Chapter 3 introduces a method for quickly assessing global competence in students and provides a detailed analysis of the quantitative results from this approach, confirmed by a more rigorous and validated assessment tool, the Global Competence Aptitude Assessment (GCAA).

Chapter 4 presents the results from using Wilde's teamology to evaluate short international partnerships, and provides guidance for better matching students with global research opportunities.

Chapter 5 presents the key conclusions from this study, highlights original contributions, and provides a roadmap for future work in assessing global competency in students and developing more effective global teams.

Chapter 2

Literature Review

This chapter reviews the concept of global competence, describes how the teamology team-building method was developed, and concludes with observations from the literature.

2.1 Global Competence

This section provides an American-centric overview of how cultures are different derived from Hofstede's model of cultures, and discusses how cultures approach problems differently. Next it presents several definitions for global competence, current programs for developing global competence in engineering students, with a focus on recent efforts at Virginia Tech. Finally, it describes how prior work in virtual collaboration and evaluating the effectiveness of study abroad programs.

2.1.1 Cultures are Different

Culture affects how people think, act, make purchases, collect information and make decisions, and impacts how they perform engineering work, define problems, and reach solutions. Culture is so fundamental that the renowned Dutch anthropologist Geert Hofstede, Ph.D., defines culture as, "the collective programming of the mind that distinguishes the members of one group or category of people from others" (Hofstede 2010).

Hofstede's theory is based on his work with IBM and on data obtained from the *Values Survey Modules* and *World Values Survey* (Hofstede 2010). Hofstede and his collaborators used statistical methods to extract six dimensions that help illuminate the cultural differences between countries.

For students to work effectively with international colleagues they need to appreciate that cultures are different, and that culture shapes how people develop and what they value (Downey 2006). Figure 1 shows the Hofstede dimensions for the United States of America (USA) and its top five economic trading partners, Canada, China, Mexico, Japan, and Germany, which account for over 60% of USA imports and exports. Table 1 lists common characteristics of the six dimension pairs, with USA dimensions masked.

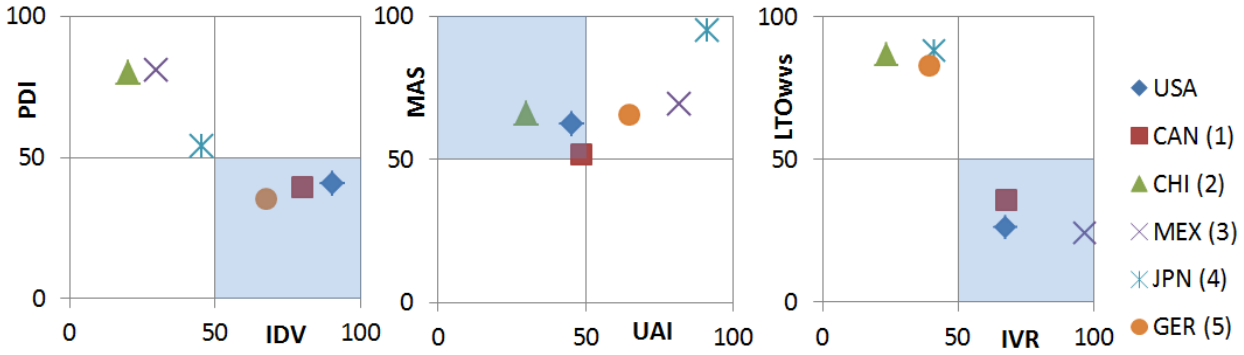

Figure 1. Hofstede cultural dimensions for the USA and its top five trading partners in rank order: Canada (1), China (2), Mexico (3), Japan (4), and Germany (5) (Hofstede 2011). See Table 1 for dimension names and descriptions.

Table 1. Hofstede Dimensions of culture with some common manifestations, with USA dimensions masked. Quoted from (Hofstede 2010).

Hofstede Dimension	Level	
	Low	High
Power Distance (PDI)	• Subordinates expect to be consulted • The ideal boss is a resourceful democrat	• Subordinates expect to be told what to do • The ideal boss is a benevolent autocrat, or "good father"
Individualism (IDV)	• Occupational mobility is lower • The employer-employee relationship is basically moral, like a family link	• Occupational mobility is higher • The employer-employee relationship is a contract between parties in a labor market
Masculinity (MAS)	• Resolution of conflicts by compromise and negotiation • Rewards are based on equality	• Resolution of conflicts by letting the strongest win • Rewards based on equity
Uncertainty Avoidance (UAI)	• Tolerance for ambiguity and chaos • Belief in generalists and common sense	• Need for precision and formalization • Belief in experts and technical solutions
Long-term Orientation (LTOwvs)	• Meritocracy, reward by abilities • Focus on the "bottom line"	• Wide social and economic differences are undesirable • Focus is on market position
Indulgence versus Restraint (IVR)	• More neurotic personalities • Thrift is important • Strictly prescribed gender roles	• More extroverted personalities • Thrift is not very important • Loosely prescribed gender roles

This important group of partners accounts for over 60% of U.S. imports and exports, and exhibit much of the cultural diversity and extremes in our world (Iseman 2011). What becomes apparent from this discussion is the clustering of countries from shared history, and the immense challenge of working amongst these different countries, much less across all cultures.

While Hofstede cautions that identifying cultures with countries and geographic boundaries in place of the source societies is perilous, he also notes that it is expedient. Downey addresses this same challenge through the use of dominant images, writing that, "even if other countries do not have single cultures, they nonetheless provide high-probability sites for encountering unfamiliar ways of thinking about engineering work" (Downey 2006). Furthermore, these Hofstede dimensions will not be reflected in the behavior of all members of a culture, but rather reflect the overall disposition of that country.

2.1.2 Cultures approach problems differently

These differences in culture cause individuals to approach problems and weigh tradeoffs differently. Understanding these differences is so essential to effective collaboration that Downey makes the claim that "the often-stated goal of working effectively with different cultures is fundamentally about learning to work effectively with people who define problems differently" (Downey 2006).

For engineers, this can relate to what methods are used to solve problems and the position of engineers in a society. Downey elaborates that, "It matters, for example, if mathematics is valued highly [France], if low cost is essential [USA], or if precision is a defining value [Germany]" (Downey 2006). It can be difficult for students to recognize and appreciate that alternate solutions exist and originate from group programming.

Even when it comes to the mundane task of learning to use a new cellular phone, culture dominates how individuals approach the problem, as shown in Figure 2. How people seek to master the latest features, by consulting an expert, combing through manuals, experimenting, or engaging their in-group all track their group programming.

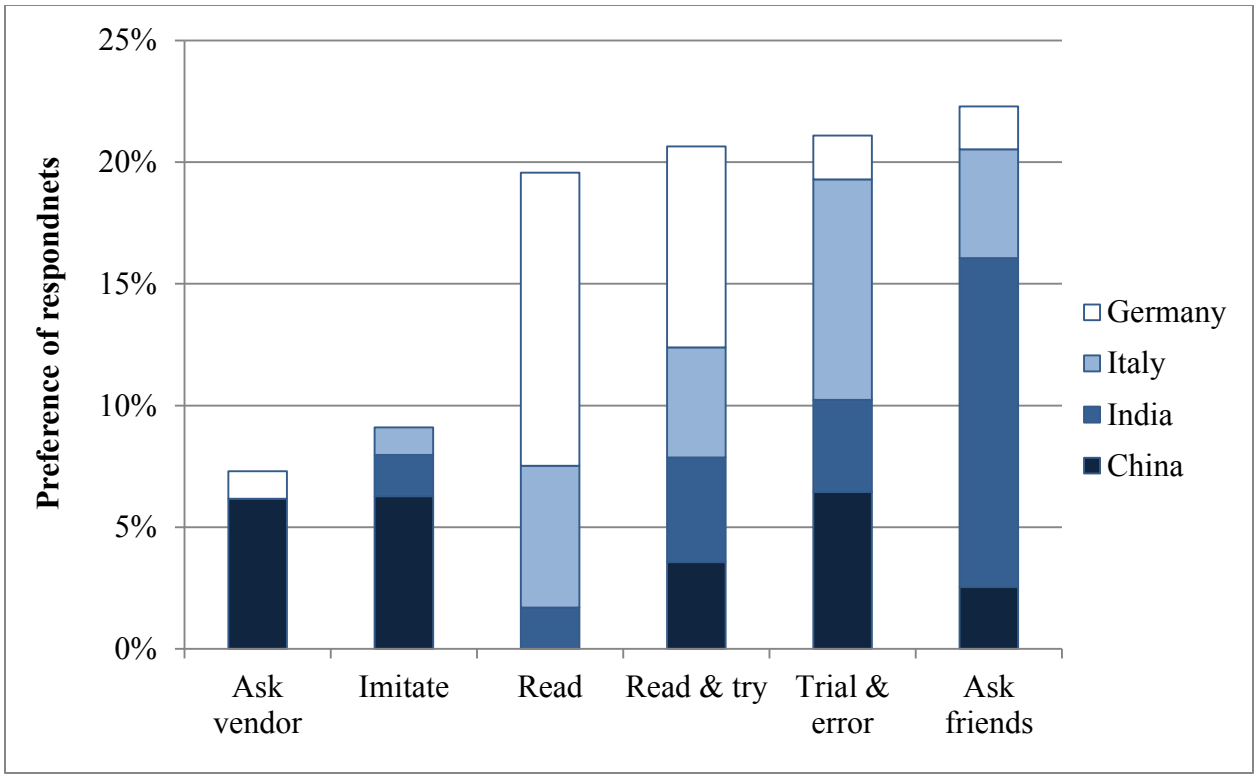

Figure 2. Dominant modes of how users in Germany, Italy, India, and China learn to use a new cellular phone. Derived from Olfs, with respondents equally weighted across countries (Hirleman 2009).

2.1.3 Defining global competency

Many authors have attempted to define global competency for engineers, while others have worked to consolidate the various definitions into a single, coherent concept (Grandin 2009, Hunter 2006). What most authors agree is that graduates need global competency to be effective in their careers (Parkinson 2009). What follows is a sample of the myriad definitions of global competency:

> "The capacity of an individual or a team to parachute into any country and get the job done while respecting cultural pathways" (Swiss Consulting Group 2002).

> "The often-stated goal of working effectively with different cultures is fundamentally about learning to work effectively with people who define problems differently" (Downey 2006).

> "Having an open mind while actively seeking to understand cultural norms and expectations of others, leveraging this gained knowledge to interact, communicate and work effectively outside one's environment" (Hunter 2006).

"[G]raduates who are able to function effectively in the global marketplace and provide leadership in the international arena" (Blumenthal 2008).

"The ability to work knowledgeably and live comfortably in a transnational engineering environment and global society" (Lohmann 2006).

Lohmann expands his definition to define basic global competency in terms of five prerequisites for graduates mirrored in the Georgia Tech International Plan (Lohmann 2006):

1. Second language *proficiency* [emphasis added]
2. International coursework
3. Immersive international experience
4. Coherent integrative program
5. Integration with student's major

From his survey of global companies, Parkinson discovered the top five qualities that graduates should possess to exhibit global competency (Parkinson 2009):

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

Fundamentally these definitions relate to a capability to perform a task, in this case engage in work with overseas colleagues, possibly in a foreign country. As this point it is important to clarify the expectations of what *competency* means on an absolute scale, which is summarized in the definitions of competency as a level of proficiency from the National Institutes of Health (NIH) and Blackwell in Table 2, and found in full in Appendix A (NIH 2010, Bird 2004). This appears to be the level expected of students graduating from college, based on the General Service (GS) Grades. This is important when discussing global competence, as not all experiences will likely result in a student becoming competent, and would fall under a lesser category of impact.

Table 2. Summary of what it means to be competent, a mid-level score in skill proficiency on the NIH and Blackwell scales. This level is approximately what engineering students would be expected to demonstrate in their professional field upon graduation. Quoted from (NIH 2010) and (Bird 2004).

Score	GS Grades	Proficiency Level	Proficiency Level	Engineering Global Competency definitions
3	7-10/11	Intermediate—practical application. Can perform skill independently, with minimal assistance	Competence—Greater appreciation for task complexity. Recognition of larger set of cues and ability to focus on most important cues. Reliance on absolute rules begins to disappear; risk taking and complex trade-offs occur.	Swiss Consulting Group Downey Blumenthal Hunter Lohmann Parkinson

2.1.4 Developing global competency

In order to help develop global competency in their students, universities send a small fraction of their student body abroad. Within engineering, these programs tend to fall within one of four categories: overseas internships, faculty-led short-term visits abroad, semester-terms abroad, or dual degree programs.

The International Engineering Program (IEP) the University of Rhode Island at stands out as an immersive program that requires significant language learning in parallel with engineering studies, in German, French, Spanish, or more recently Chinese. URI's partnership with Technische Universität Braunschweig is noteworthy for having exchanged 300 students in 10 years (Grandin 2006). The University of Michigan and Shanghai Jiao Tong University stand out as pioneers in the field of collaborative engineering education with their Joint Institute, which was officially formed in 2006 (Ni 2011).

In his review, Parkinson provides descriptions of these and other significant global engineering programs, while Hirleman offers a first-look at comparative analysis of global experiences (Parkinson 2009, Hirleman 2009). Ranging from perceived high-impact, low participation programs (higher cost, more intensive) such as GEARE, through Internet-based global design projects (lower cost, less impact), Hirleman's work offers a framework for addressing the tradeoffs between programs. As a way of further enhancing these programs, Del

Vitto leans on the experiences of corporations and advocates that these programs provide students with cross-cultural training (Del Vitto 2008).

In 2012, Virginia Tech will start its 5th year of a National Science Foundation Research Experiences for Undergraduates (NSF REU) program. This program provides funding for students to engage in summer research projects at Virginia Tech, USA, and Technische Universität Darmstadt (TUD), Germany, with a focus on automotive technologies.

More recently, Virginia Tech and TUD have instituted dual degree programs for Bachelor of Science and Master of Science in Mechanical Engineering. Students in these programs spend one year at the partner university taking a full engineering course load or performing research in the host country language. American engineers must demonstrate capability with both spoken and written German in order to be considered for this intense program.

2.1.5 Americans and Germans *are* different

Virginia Tech's partnership with TUD provides select students with an opportunity to experience engineering at a top university that instructs students in a different approach to the art of engineering. As Downey notes, these differences form dominant images that shape the profession of engineering in the USA, and differ drastically from those important to Germany, and are summarized in Table 3 (Downey 2005). Of paramount importance to engineers in the USA is the economic impact of a new product, while in Germany it is essential that engineers obtain an intimate understanding of the product to instill precision.

Table 3. Dominant Images of the engineering profession in the USA and Germany, from (Downey 2005).

USA	Germany
Increasing standards of living	Quality
Low cost, mass use	Progress
	Nationhood

This differing approach to engineering, material versus transcendental, is reflected in Figure 3 from Hofstede's work, most visibly in the differences in Long-term Orientation and Indulgence versus Restrain between these nations. The "garage company" mentality of experimentation that brought about industrial greats HP and Google in the USA fits with our nation's image as tinkerers (empiricists) while the mere mention of German (old) companies such as BMW or Bosch invoke images of quality and precision. Rapaille echoes this sentiment in his widely read book, *The Culture Code*, identifying the American code for quality as "IT

WORKS," and the German code for automobiles as "ENGINEERING" (Rapaille 2006). In fact, the German automaker Audi recently released an advertising campaign with the slogan, "Truth in Engineering™," and their core motto, "Progress through Technology" (Audi 2011).

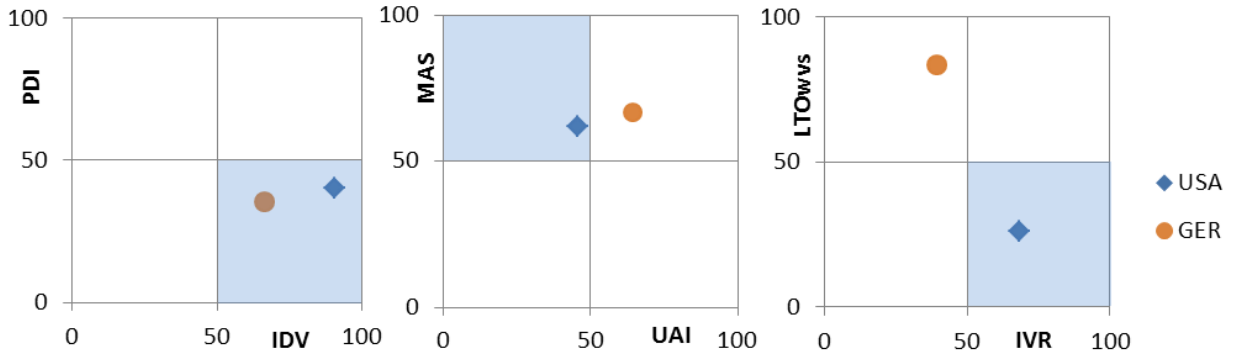

Figure 3. Hofstede dimensions for the USA and Germany, showing substantial difference in Long-Term Orientation (LTOwvs), and smaller differences in Individualism (IDV), Uncertainty Avoidance (UAI), and Indulgence vs. Restraint (IVR). Similarities are shown in Power Distance (PDI) and Masculinity (MAS).

Globalization has received increasing scholarly and media attention as a result of Thomas Friedman's *The World is Flat*, which discusses how companies are expanding internationally to cut costs, reach new customers, and tap new talent (Friedman 2006). Hofstede's work and that found in other global management texts provide a starting point for transnational workers to anticipate how cultural differences will impact their working lives, and offer insight into the engineering and decision making processes (Hooker 2003, Harris 2000). For students or professionals working between the USA and Germany, these differences can be significant, as outlined in Table 4.

Table 4. Sampling of cultural images from management textbooks highlighting some differences between Americans and Germans (Hooker 2003, Harris 2000, Meredith 2007, Moran 2007, Lewis 2000).

	Americans	Germans
Hierarchy	Flexible	Ordered
Patience	Low	High
Patriotism	Outward	Subdued
Protocol	Loose/friendly	Rigid/private
Risk aversion	Low	High
Working hours	All-day	Business hours

2.1.6 Intercultural Encounters

Recognizing cultural differences is essential to effective collaboration, as Hunter explains that, "A globally competent person must be able to identify cultural differences to compete globally, collaborate across cultures, and effectively participate in both social and business settings in other countries" (Hunter 2006). However, Downey notes, "people in the U.S. tend to highlight similarities across cultures while minimizing differences" (Downey 2006). This puts Americans at a disadvantage when they work with foreign colleagues.

From her work observing a collaborative design project involving students from Virginia Tech, USA, and The Royal Institute of Technology (KTH), Sweden, Paretti et al. conclude that:

> "Students in the partnership tended to attribute challenges in the collaboration to cross-disciplinary rather than cross-cultural conflicts. When discussing problems, they were more likely to point to different course goals and different disciplinary expectations regarding the work, rather than to analyze cultural differences between U.S. and Swedish approaches to work" (Paretti 2006).

While it is reasonable to expect difficulties in collaborating across disciplines, it is telling that students minimized the importance of cultural differences to their collaboration. As shown in Figure 4, the USA and Sweden show several significant cultural differences, particularly in the Hofstede cultural dimensions of Masculinity and Long-term Orientation, which each substantially impact the way work is performed in these countries, and how solutions are defined. Echoing this in *Modern Day Vikings*, Robinowitz and Carr discuss how the concept of quality differs between the USA and Sweden:

> "In Sweden quality implies something that is well designed, that always works, and that lasts a long time…Swedes in the United States often complain about the lack of care and craftsmanship they see in homes, cars, and household items. They criticize 'disposable' products, and 'buy quality; cry once' is their motto" (Robinowitz 2001).

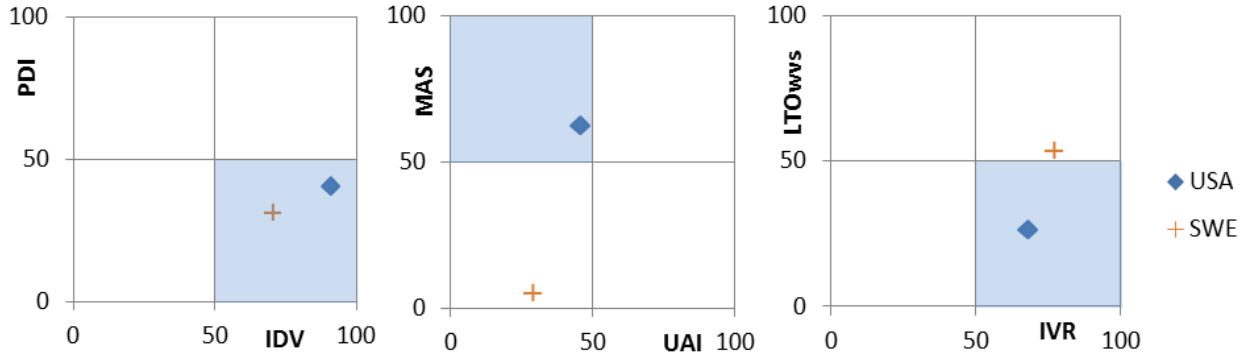

Figure 4. Hofstede Dimensions for the USA and Sweden, showing significant differences in Masculinity (MAS) and Long-term Orientation (LTOwvs). Some difference exists in the dimensions of Individualism (IDV), Uncertainty Avoidance (UAI), with less difference shown in dimensions of Power Distance (PDI) and Indulgence vs. Restraint (IVR).

2.1.7 Assessment results from study abroad

Lohmann notes that while the field of global competency is gaining increasing interest, little literature exists to assess and quantify the criteria set forth in his definition of global competency, and that most studies provide, at best, self-reported gains from students (2006). Additionally, group comparisons and rigorous assessment are largely non-existent. As a baseline for assessing the efficacy of the Georgia Tech International Plan, Lohmann shows a significant difference in self-assessed confidence between recent graduates who studied abroad while at Georgia Tech and those who did not, in the areas of global engineering, leadership skills, interpersonal conflict resolution, and foreign language (Lohmann 2006).

One notable paper on assessment comes from Medina-López-Portillo, who used a standardized tool, Hammer's Intercultural Development Inventory (IDI), to compare students who engaged in short summer programs abroad using pre- and post-experience testing (Medina-López-Portillo 2004). Students in the 16-week program were more likely to advance to the next DMIS development stage than students in the 7-week program. Of note, few students achieved ethnorelativism, and students in both groups continued to overrate their competency even after participating in their respective programs, as shown in Table 5.

Table 5. Results from Medina-López-Portillo's investigation of study abroad program length and student gains in Intercultural Sensitivity (Medina-López-Portillo 2004).

Program duration (weeks)	Students in the study	Pre/Post experience DMIS score changes			Average perceived DMIS level discrepancy, relative to actual score	
		Drop	No change	Gain	Pre	Post
7	16	2	11	3	+1.9	+1.9
16	9	3	0	6	+1.6	+1.2

2.2 Global Competency Aptitude Assessment

Past experiences with the Intercultural Development Inventory (IDI) failed to show significant distinctions or consistency between student groups, as other studies have shown, and assesses only Intercultural Sensitivity (Bøhn 2006). The Global Competency Aptitude Assessment (GCAA) represents the state-of-the-art in assessing global competency, providing scoring and feedback on eight areas covering Internal Readiness and External Readiness Characteristics, as outlined in Table 6 (GCAA 2011). This validated assessment tool is based upon Hunter's definition and model of global competency, and provides users with a detailed report and suggestions for further development of their deficient characteristics.

Table 6. The eight dimensions of the Global Competency Aptitude Assessment®, with Self-Aware noted as the most critical component (GCAA 2011, Hunter 2006)

Internal Readiness Characteristics (Traits and Attitudes)		External Readiness Characteristics (Knowledge and Skills)	
Knowledge of Self	*Learning from Others*	*Education*	*Experience*
1. Self-Aware*	2. Willing to Take Risks	5. Knowledgeable about World History	7. Interculturally Competent
	3. Open Minded	6. Globally Aware	8. Effective Across Cultures
	4. Perceptive and Respectful of Diversity		

These characteristics manifest in the knowledge, skills, and abilities necessary for global competence, as determined through Hunter's work with global professionals and educators. From earlier work, knowledge of one's own culture ("Self-Aware") is identified as the launching point for developing global competence, with the expectation that students "develop a keen understanding of his or her own cultural norms and expectations" (Hunter 2004, Hunter 2006).

2.3 Teamology

Beyond needing to provide students with the tools and experiences to become globally competent, there is a need for better matching students with team-based opportunities to ensure high performance. Teamology is a methodology for assembling teams to maximize their creative output and was developed by Douglass J. Wilde, emeritus professor of Mechanical Engineering at Stanford University (Wilde 2009). Teamology works by balancing the Jungian cognitive modes of members on a team, thereby enhancing the ability of the team to effectively collect information and make decisions.

The foundation of Teamology is drawn from Belbin, whose experiments involving teams identified roles necessary for teams to function well (Wilde 2009). While Belbin showed that effective teams required certain work types in order to function effectively, Wilde has shown that these roles are not merely random, but instead tied to the dominant traits of personality. To this framework of team roles Wilde added the Myers Briggs Typology Index, and later a shortened version that requires only twenty questions to identify personality types. Wilde summarizes this concept writing, "The basic idea is to have every team possess among its members the full range of problem-solving approaches available to the human race" (Wilde 2009, Wilde 2010).

In his evolving theory, Wilde found that the number of these roles that a team covered impacted their winning potential, with each role covered roughly increasing the level of the prize awarded to the team, such as from honorable mention to silver.

Over the course of nearly two decades, Wilde has shown dramatic improvement in student design teams performance at the national Lincoln Arc Welding Foundation awards through the use of his research on personality types and design team roles. In describing the impact of his methodology, Wilde claims that, "Using these methods will make an entire team project class perform as well as what would be, without them, the top quartile" (Wilde 2009). Wilde has used his method to arrange teams in order to maximize the potential of individuals on teams, thereby enhancing team performance.

Importantly, when personality type-based team composition was halted at Stanford in 2000, team performance reverted to the original levels, and rebounded the following year when this process was returned. Interestingly, Wilde found that strong preferences are not nearly as important as having all roles covered, and may in fact lead to disharmony (Wilde 1999). After numerous revisions and iterations to his theory, Wilde settled on 16 necessary roles, and developed his Teamology method of designing groups which are balanced for collecting information and making decisions (Wilde 2010).

2.4 Observations

While the fields of global engineering and team management are broad, the literature on global competence and teamology suggest the following:

1. Many common commercial global assessment tools are not country-specific, and rely on student self-assessment.

2. From reviewing Hofstede's model of the overall complexity of the cultures students could encounter, it is unlikely that students will be effective (competent) across all cultures from the limited exposure they could experience while in school. A more reasonable goal might be to target competency for a country or region first.

3. Downey, Paretti, and Hunter all indicate that students need to be able to recognize cultural differences and overcome the American tendency to seek sameness. Seeing difference and similarities is essential to working effectively as global engineers.

4. Olf's data on how individuals in different countries learn to use cellular phones has implications when sharing technologies between countries, as these differences in how information is disseminated could pose significant challenges to success if only presented in the dominant format from the home nation.

5. Prior studies have evaluated intercultural sensitivity, not the attainment of the myriad definitions of global competency or how this impacts students' ability to work effectively in a global workplace.

6. Medina-López-Portillo shows that students tend to overestimate the impact of study abroad on their intercultural sensitivity.

7. Teamology is useful in predicting both team behavior and how individuals might act on a team. Knowing this, team leaders can better manage the composition of their teams to enhance performance.

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Chapter 3

Global Competence Survey

This chapter describes the development of the Global Competence Survey (GCS). In contrast to other survey instruments that aim to assess global competencies, this survey instrument is specifically designed to be relatively fast to complete so as to encourage a high response rate. It maintains a narrow scope and measures competency relative to only a single, specific country of interest. In this first iteration, the GCS is designed for U.S. participants relative to Germany. The results for its initial deployment are presented and evaluated relative to a commercially available comprehensive survey instrument. This chapter is presented in the format of a journal paper manuscript.

Global Competence Survey

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Abstract

Significant resources are being invested in education abroad activities. The objective is to enhance the global competencies of students, and make them more competitive and successful in the increasingly global economy. The methods of education abroad are diverse, and there is a need to better understand the relative effectiveness of these various methods, especially as the U.S. aims to grow U.S. education abroad participation from less than 2% today to more than 50% over the next several years. Current instruments for measuring global competencies are used infrequently, as they are costly and require significant efforts by the participants to complete, and often provide poor guidance. Education abroad programs tend to serve small cohorts, which when coupled with traditionally low response rates, tend to provide limited confidence in assessment results. This paper describes a new focused survey instrument that requires minimal time for the participants to complete and that is kept short by making it country-specific. Results show that it produces very high response rates and can clearly distinguish between the levels of global competencies achieved by several different education abroad experiences.

3.1 Introduction

The U.S. Government, foundations, and U.S. universities invest significant resources in education abroad programs for U.S. students, and the trend is towards increasing these investments. The expectation is that education abroad experiences increase global competencies, and that these competencies will be critical for success in the global economy. Education abroad experiences span a wide range and combinations. They may focus on the degree-technical domain of the student, or they may have a general education focus; they may focus on course work, or they may be applied such as in the form of an internship; they might be based on the native language of the student, or they may include language and culture training; they may be faculty-led or independent immersion by the students; and they may be for as little as a week or two, or they may span a semester, year, or more.

In 2010, only 1.36% of U.S. undergraduate students have credit-bearing education abroad experiences (NAFSA 2010). The Commission on the Abraham Lincoln Study Abroad Fellowship Program, which is a bi-partisan commission appointed by the United States Congress and the President, has set the goal of increasing U.S. education abroad participation to one million students per year within a decade (Lincoln 2005), which would represent approximately two out of every three undergraduate students (IES 2008). With this expected strong growth in education abroad participation, it is essential that this massive influx of students are directed towards the more cost-effective methods for developing global competency within the vast portfolio of available options.

Unfortunately, the effectiveness of various education abroad methods in this regard is poorly understood individually, and they have not been objectively compared relative to each other. Most education abroad programs typically assess participant self-satisfaction and logistic concerns. Their data sets tend to be small and their response rates tend to be low. Taken together, this makes it challenging to extract data that can provide more meaningful insight than what is observed anecdotally by the program organizers.

Of keen interest to program organizers are commercial instruments developed to measure global competencies. The Intercultural Development Inventory (IDI) is a 50-item instrument that is widely used to assess student development during education abroad experiences. It appears to measure growth in students who participated in long-term experiences of at least one semester and preferably of a year, when students were coached (Pedersen 2010). However, its validity is less definitive for short-term experiences (Anderson 2006), which are the dominant mode for students U.S. students, as illustrated in Table 7. In the extreme, the IDI was unable to measure any impact of a two-week abroad experience by U.S., German, and Mexican mechanical engineering students (Bøhn 2006).

Table 7. Approximate number of study abroad students from Virginia Tech, sorted by duration of term abroad (Miller 2011)

Number of students	Program duration
15	Academic year
300	Semester-length
900	Short-term (2-4 weeks)

A more recent commercial instrument is the Global Competence Aptitude Assessment (GCAA) (Hunter 2004), which attempts to go beyond intercultural sensitivity by also measuring willingness to take personal risk outside one's comfort zone, global awareness (including cross-border interactions, trade, geography, etc.), knowledge of world history, and being effective across cultures, so as to collaborate and work effectively within and across perceived or actual cultural barriers.

Unfortunately, these commercial instruments are frequently unsuitable in today's education abroad market place. One serious issue is cost, given that most education abroad programs operate with minimal budgets and are incapable of paying $50-100 per participant to evaluate student competency through the various stages of their education abroad experience. A second serious challenge is achieving meaningful assessments from small populations with low response rates. These instruments tend to require careful coordination with an outside firm, and are rather time-consuming to complete. As a result, few students take them.

Hence, there is a need for an inexpensive, quick, and effective assessment tool to measure the impact of education abroad experiences on the development of students as global citizens. This paper describes the development of the Global Competence Survey (GCS), a new high-resolution assessment instrument designed to be quick for the participants to complete, in order to encourage high response rates. To do this, the instrument does not attempt to be general purpose, but rather is designed for a single-destination country. The next section will describe the initial population groups that were targeted and the structure of the resulting country-specific assessment instrument. This is then followed by an analysis of the results that were obtained by applying this instrument to the target population groups, including its ability to delineate between domestic, short-term education abroad, and yearlong education abroad students based upon factual questions and dominant cultural images. Finally, these results are compared with those of the GCAA using the same populations.

3.2 Experiments

With the increasing focus on globalization and the growing integration of education abroad programs into curricula, there is a need for an inexpensive, quick, and effective assessment instrument to measure the impact of education abroad on the development of students as global citizens. This section describes the development of the GCS to address this need. First it describes the target population groups for the GCS, and then describes the design of the GCS.

3.2.1 The Study Participants

Assessment of student growth in global competence is typically performed using pre- and post-experience testing. Most show minimal growth regardless of duration (Anderson 2006, Pedersen 2010), unless complemented with awareness training (Pedersen 2010). The reason for this might be that the instruments used for these studies lack adequate resolution to detect changes due to the experience abroad itself, hence the need to coach the students in what they observe while abroad. Also, the instruments may have been administered too soon after repatriation to assess student growth due to continued processing of changes upon return home (Medina-López-Portillo 2004). Alternately, it might be because these participants often are heterogeneous with regards to academic background and preparation, and do not form a coherent population group capable of being fairly compared.

This study attempts to reduce variability by selecting participants of similar academic background and with a similar destination abroad, though with different durations. Specifically, in this study all the participants were U.S. mechanical engineers and the destination of interest was the Technische Universität Darmstadt (TUD) in Germany. These relatively uniform populations differed only in their education abroad experience: (1) undergraduate research at Virginia Tech; (2) undergraduate research at Virginia Tech involving virtual collaboration with colleagues at TUD; (3) undergraduate research at TUD; and (4) an academic year at TUD. Hence the focus of this study was on detecting the impact of these various modes of education abroad experiences on the students' development as global engineers.

The first group was the control group population: It consisted of mechanical engineering students that had been enrolled in the course *ME 4994 Undergraduate Research* (ME4994) under various advisers at Virginia Tech. These students were embedded in a graduate research team at Virginia Tech and received no education abroad exposure during this activity.

The second group consisted of mechanical engineering students that participated in a U.S. National Science Foundation (NSF) Research Experiences for Undergraduates (REU) in the area of automotive technologies over a period of eight week during a previous summer. They had been embedded in a graduate research team at Virginia Tech, but, unlike the control group, they had participated in a transatlantic research project with colleagues at TUD. This experience

involved daily interactions by videoconference and other Internet communication technologies with their colleagues overseas.

The third group also consisted of mechanical engineering students that had participated in a NSF REU in the area of automotive technologies over a period of eight week during a previous summer, but these students were embedded in a graduate research team at TUD. The language of their interaction at TUD was English.

The fourth group consisted of students were enrolled in coursework for either the dual Bachelor of Science in Mechanical Engineering degree program (dual BSME) or in the dual Master of Science in Mechanical Engineering degree program (dual MSME) between Virginia Tech and TUD. These students had completed at least 12 semester credit hours of German language instruction at Virginia Tech, followed by six weeks of additional language instruction TUD prior to their semester start at TUD. At the time of assessment, these students had all lived and studied for 9 months at TUD. The language of instruction at TUD was German.

With access to these four populations of U.S. mechanical engineering students and a single destination abroad, one objective was to craft a tool capable of assessing global competence, and a second objective was to evaluate whether any differences existed between these four student groups. Such information could be useful in designing future study abroad opportunities for engineers, and for cost-benefit analysis of existing formats.

3.2.2 Developing the Global Competence Survey

Downey defines global competency for engineers as the knowledge, ability, and predisposition to work effectively with people who define problems differently than they do (Downey 2006). To successfully achieve this level of proficiency requires one to have some factual knowledge of one's home country and that of one's colleague, and be able to recognize and compare some basic cultural cues of these two countries. The objective of the Global Competence Survey (GCS) is to briefly sample a participant so as to quickly gauge to what degree this fundamental knowledge and cultural understanding is present.

The first iteration of the GCS was developed for U.S. participants engaging with colleagues from Germany, and was designed with help from Steven Culver, Associate Director of the Office of Academic Assessment and Evaluation at Virginia Tech. The factual awareness questions concerning the U.S. and Germany were designed to gauge and capture a few sample facts that one might expect someone engaging with colleagues in these countries over time to be familiar with. The cultural trends questions were derived from research results on how people in the U.S. in particular tend to perceive members of a different culture (Bird 2004, Harris 2000,

Hooker 2003). These latter questions were then reformulated to test whether participants could reasonably compare these cultural trends.

The resulting GCS consists of 51 questions across three sections and takes 10-15 minutes to complete. The first section explores key factual knowledge about the USA and Germany, each country is assigned 9 multiple-choice questions. By design these questions form sets of corresponding pairs, which permits a reasonable comparison of the depth of knowledge for each country. An example of this reflectivity is shown in Figure 5.

Question 7 (USA): America was part of a coalition of allies in the Second World War, including all of the following except:

Britain Sweden Canada USSR Not sure

Question 16 (Germany): After being decimated in the Second World War, much of Germany was rebuilt through which plan:

Churchill Marshall Mitchell Potsdam Not sure

Figure 5. Example of a corresponding pair of factual and historical knowledge questions concerning the USA and Germany, respectively. The correct response is highlighted in yellow. These are two of 18 questions in this first section.

The second section in the GCS consists of culturally focused questions in a True/False format. Again, these questions have reflective pairs, one for each country, to facilitate a fair comparison of knowledge of these two countries: Each country is assigned five True/false questions, and one of these pairs is shown in Figure 6. The True/False question style was used in this section as an alternative to multiple-choice format, since this was a new tool and the best format for questions was unknown. Several of the question pairs were identical except for the country that it refers to, such as the questions shown in Figure 6, and as such this question format thus also provides a transition for the participants into thinking of cultures in terms of dominant tendencies when performing work.

Question 21 (USA): Americans tend to be quick to make decisions

T F Not sure

Question 26 (Germany): Germans tend to be quick to make decisions

T F Not sure

Figure 6. Example of cultural tendencies and factual questions presented in a True/False format. The correct response is highlighted in yellow. These are two of 10 questions in this second section.

The third and final section of the GCS assesses the ability of the participants to differentiate between cultural trends in a comparative format. The questions in this section have been derived from the descriptions of dominant U.S. and German cultural images as found in the research literature in the context of Hofstede's broader model of cultures (Hofstede 2010). Three

of these 23 questions are shown in Figure 7. As with the first two sections of the GCS, these questions were by approximately split between the U.S. and Germany: 10 questions described cultural tendencies that are more prevalent among people in the U.S.; 9 questions described cultural tendencies that are more prevalent among Germans; and 4 questions described tendencies that are more or less equally prevalent among people from the U.S. and Germany.

On average, which peoples are more likely to:		(A) Americans	(B) About equal	(C) Germans
Question 29:	Expect a high degree of equality and opportunity		X	
Question 34:	Be concerned about the risks of genetically modified (GM) foods			X
Question 40:	Open displays of patriotism are the norm	X		

Figure 7. Example of cultural awareness questions that ask the participant to categorize correctly cultural norms as (A) predominately American, (B) equivalent across either cultures, or (C) predominately German. The correct response is highlighted in yellow. These are three of 23 questions in this third section (Hofstede 2010, Hooker 2003, Harris 2000, Lewis 2000, Meredith 2007, Weise 2010, Angelos 2010).

Taken together, these questions are designed to briefly sample U.S. participants so as to quickly gauge to what degree they have a fundamental knowledge and cultural understanding with regards to Germany and USA. The following section will discuss the results of applying the GCS to the study participants described earlier, and then compare these results to those from the GCAA.

3.3 Results and Discussion

The Global Competence Survey (GCS), developed for this study, and the commercial Global Competence Aptitude Assessment (GCAA) were distributed during Summer 2010 to the following four population groups:

1. Control: Students having recently completed undergraduate research in mechanical engineering at Virginia Tech (VT), embedded in a graduate research team;
2. REUVT: Students that had participated in a U.S. National Science Foundation Research Experiences for Undergraduates (NSF REU) project, working in English, embedded in a

graduate research team during a summer at VT, involving virtual collaboration with colleagues at the Technische Universität Darmstadt, Germany (TUD);

3. REUTUD: Students that had participated in a NSF REU project, working in English, embedded in a graduate research team during a summer at TUD; and
4. Dual: Students that had just completed nine months at TUD, taking engineering courses in German as part of either a VT-TUD dual-Bachelor or dual-Master degree program in mechanical engineering.

The objective was to see if the GCS and GCAA could distinguish between these four population groups and show a measureable value to various education abroad formats. The following will therefore examine the impact of virtual collaboration, the impact on factual knowledge and the understanding of cultural images, before comparing the capabilities of the GCS and GCAA.

3.3.1 Impact of Virtual Collaboration as an Alternative to Study Abroad

Virtual collaboration is becoming increasingly more common with the rapid growth of globally distributed project teams. Students must therefore not only become competent in working within multidisciplinary project teams, but also within globally distributed project teams using virtual collaboration tools on a daily basis. The question is, do students that engage in globally distributed virtual project teams increase their global competencies?

Students in globally distributed project teams quickly learn to technically operate virtual collaboration tools and adapt them to their given situation, such as shifting from audio-visual to instant message collaboration when the spoken language skills are problematic. For instance, typing brief messages instead of speaking them gives one more time to find the words and phrases that one is searching for, and information is not lost to mumbling and heady accents.

However, it is not clear that students measurably grow their cultural competencies in a virtual environment. Previous experiments using the Intercultural Development Index (IDI) have been discouraging (Bøhn 2006), and, in this experiment, preliminary review of the GCS data was unable to distinguish between the control group (Control) and those that added transatlantic virtual collaboration to their experience (REUVT). Because of this, these two groups were pooled together in both the GCS and GCAA as the Control group to slightly strengthened the reliability of the results.

3.3.2 Comparing the Response Rates of GCS and GCAA

100 participants were invited to participate in the GCS, and were provided access to the GCAA if they completed the GCS. This includes 73 in the combined control group (Section 3.3.1); 21 in the undergraduate summer research program in Germany; and six in the USA-German dual degree programs in mechanical engineering, as outlined in Table 8.

Table 8. Participant rates of the three student populations in this study.

Student group	Contacted	GCS Respondents	GCAA Respondents	GCS Participation	GCAA Participation
Control	73	23	10	32%	14%
REUTUD	21	18	12	86%	57%
Dual-degree	6	5	2	83%	33%
TOTAL	100	46	24	46%	24%

The response rates between these three populations varied significantly. The combined Control group had 23 respondents (32%) complete either the GCS or the GCAA. In comparison, the REUTUD and Dual-degree groups had 18 (86%) and 5(83%) respondents respectively. A closer look at the combined control group shows that the original control group (ME4994 Undergraduate Research at Virginia Tech) had a 24% response rate versus 72% for the REUVT. These higher response rates for the REUVT, REUTUD, and Dual-degree population are probably due to the participants' personal relationship with the principal investigator who requested their participation in the surveys. Such a pre-existing relationship did not exist with the ME4994 participants.

More interesting, however, is the large difference in GCS and GCAA response rates for all three populations. Overall, the GCS had a 46% participation rate while the GCAA had a 24% participation rate. This spread ranged from 20 percentage points (Control) to 50 percentage points (Dual-degree). The impact of this large spread is significant in that with small populations one seldom can afford to have a low participation rate if one is to draw conclusions with confidence. Since education abroad cohorts are often relatively small, it is therefore critical to have high participation rates, especially when comparing experiences with relatively similar outcomes.

The GCS was designed to focus on a few critical dimensions (current and historical facts; and cultural tendencies and dominant images) in the context of a single country pairing (USA-Germany). The GCAA spans eight dimensions and attempts to be more general in its geographic applicability. Consequently, the GCS can be completed in approximately 10-15 minutes while the GCAA requires about 35-45 minutes to complete. This time difference is significant, and it

appears to be the key factor determining if a participant will volunteer to complete the survey or not. Clearly the design of the GCS was successful in attaining a response rate that is superior to that of the GCAA, and critical to assessing small cohorts.

3.3.4 Analysis of the GCS

In total, 46 respondents completed the entire GCS and were included in this study. The control group included 24 students who worked at Virginia Tech as Undergraduate Researchers or domestic REU students (Control), while the main study abroad group included 18 students who completed a two-month REU at TUD (REUTUD). These groups were chosen to permit statistically-backed inferences about the impact of study abroad.

An additional group of five students were included for comparison as they who spent a full-year abroad studying at TUD (Dual-degree). While this group was small, it tends to reinforce the importance of study abroad and indicates an improvement over the performance of the REUTUD group.

The results of the GCS show that these three groups, domestic, short-term, and long-term abroad, are distinct groups when it comes to understanding cultures. The student responses were scored and processed using one-way ANOVA in JMP to determine whether a statistically significant difference distinguished these three groups. Many of the results in this study show strong statistical significance, as defined with a Probability > F of less than 0.05, and statistical significance, as defined with a Probability > F of 0.10, as summarized in Table 9. Respectively, these mean that there is less than at 5% or 10% chance of wrongly ascribing distinction where none exists.

Table 9. Summary of the ANOVA results from the GCS across all three populations. Statistically significant results highlighted in blue, with an asterisk (*) indicating strong statistical significance.

Section of the GCS	Probability > F
USA factual	0.0336*
German factual	0.0006*
USA True/False	0.2973
German True/False	0.0566
Overall culture matching	0.043*
USA cultural	0.1253
Similar cultural	0.2847
German cultural	0.0008*
Rejecting sameness	0.1371

3.3.4.1 Historical and factual questions

When asked historical and factual questions on the USA, the Control group and the REUTUD groups scored similarly, while the Dual-degree students performed substantially better. As shown in Figure 8, the Dual-degree students have a higher mean than the study average, as indicated by the centerline of the green Dual-degree rhombus relative to the black centerline that crosses all three categories. Additionally, the normal quintile plot shows mostly parallel trend lines on all figures, which indicates reasonable normality between the groups, and allows for comparison of the three populations. When asked the reflective factual and historical multiple-choice questions on Germany, the three student populations stratify as expected, with the Dual-degree students outperforming the REUTUD students, who in turn outperform the Control group, as shown in Figure 9.

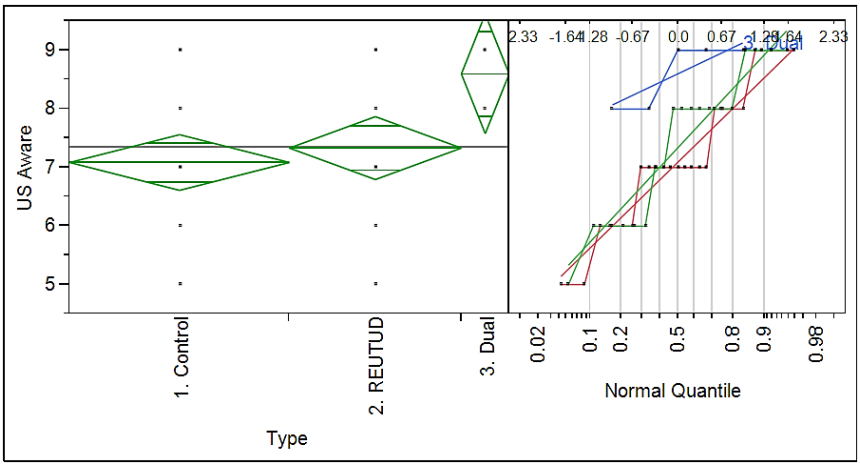

Figure 8. American factual and historical questions, showing that the dual degree exchange students perform significantly better than either the domestic control group or short-term REUTUD researchers. Showing strong statistical significance with a Prob > F 0.0336. Questions 1-9.

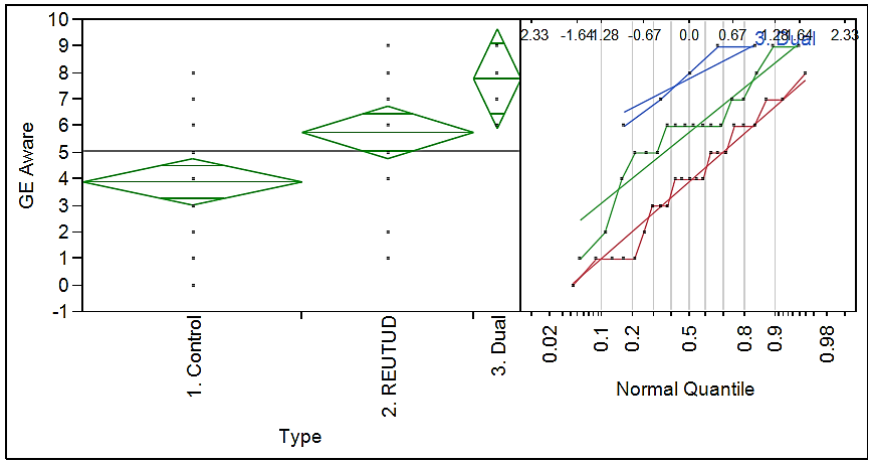

Figure 9. Student scores on German factual and historical questions, showing a very strong statistical significance with Prob>F 0.0006. Question 10-18.

3.3.4.2 True/False questions

When asked questions in the True/False format about American cultural and factual questions, there does not appear to be a significant difference between the three student populations, as shown in Figure 10. However, when asked equivalent questions True/False questions about Germany, the three groups again stratified as expected, with the Control group answering the fewest questions correctly, and the Dual-degree students answering the most correctly. The Dual-degree students had scores for German questions on par with how the Control group performed with USA questions, as shown in Figure 11.

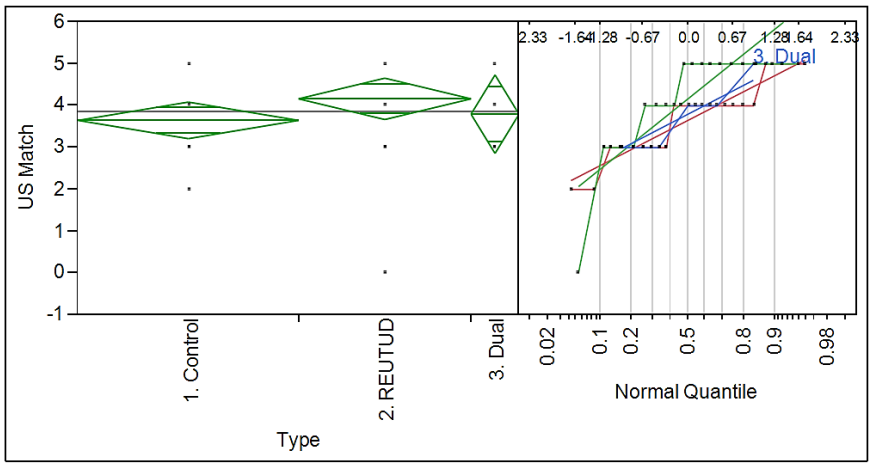

Figure 10. American T/F questions. No statistically significant differences detected, with Prob>F = 0.2973. Questions 19-23.

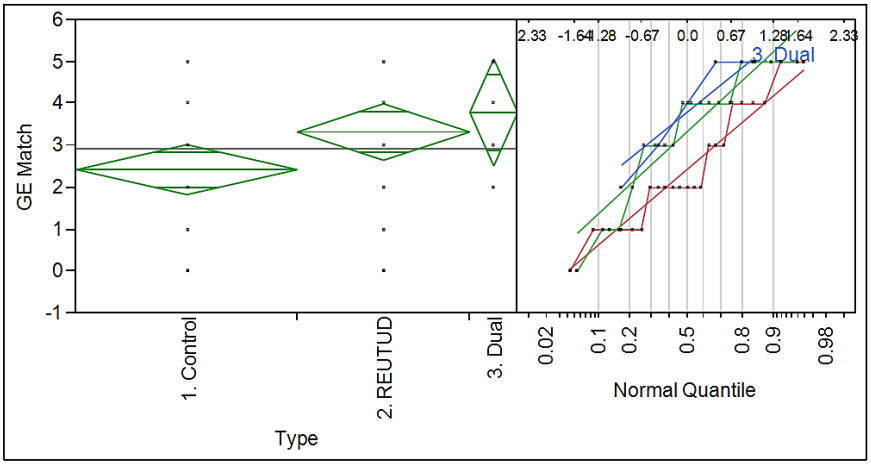

Figure 11. German T/F cultural and factual questions, showing moderate statistical significance with Prob> F 0.0566. Questions 24-28.

3.3.4.3 Comparing cultural tendencies

When asked to compare the cultural tendencies of Americans and Germans, the REUTUD and Dual-Degree students similarly outperformed the Control group, as shown in Figure 12. For further analysis, this section was broken down into four subsections centered on correctly answering American (Figure 13), Neutral (Figure 14), or German culture questions (Figure 15) correctly, and when students answered questions incorrectly and chose the culturally neutral answer (Figure 16).

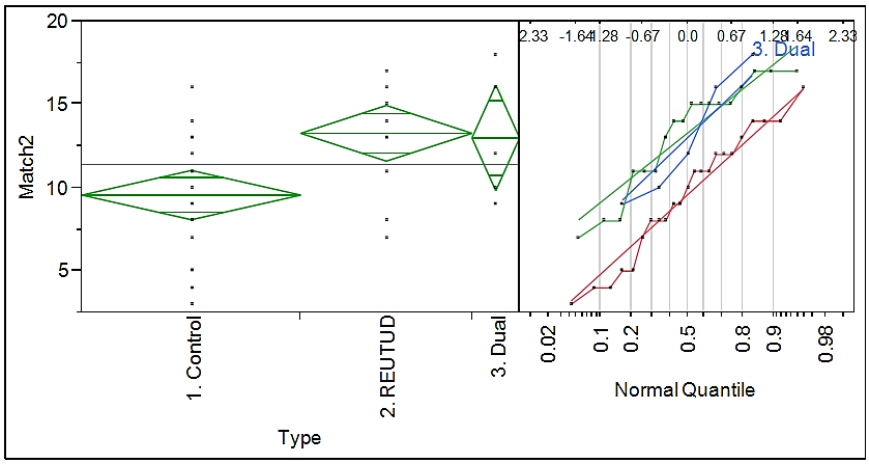

Figure 12. Culture match with all questions, American, About the same, and German, showing strong statistical significance with Prob> F 0.043. The REUTUD and Dual students significantly outperform the Control group on this section of the GCS. Questions 29-51.

For questions on U.S. cultural tendencies, there was no perceptible difference between the three student populations, as shown in Figure 13. These questions do not serve to distinguish the groups in a meaningful way, unlike the earlier factual questions on the USA, as shown in Figure 8. The student groups performed similarly in identifying similar cultural tendencies, as shown in Figure 14. However, the groups diverge when it comes to correctly identifying German tendencies, as shown in Figure 15. The Dual-degree and REUTUD students perform substantially better than the Control group on this section.

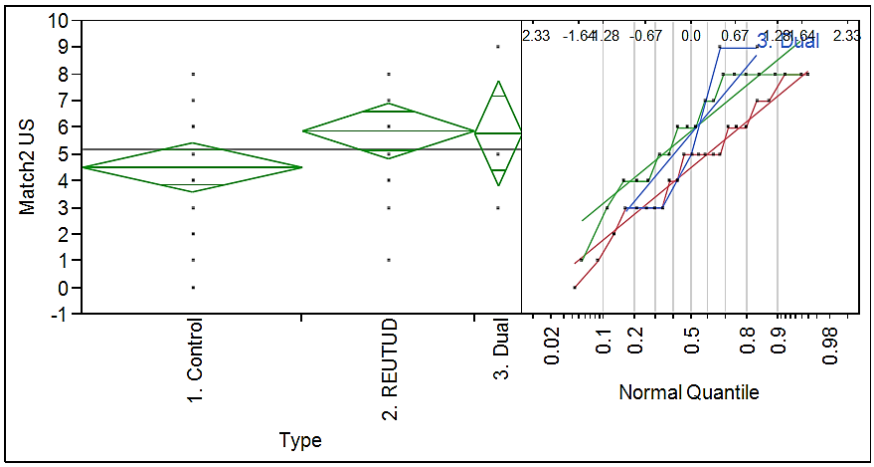

Figure 13. U.S. cultural tendencies show no statistically significant difference between the populations, with Prob>F 0.1253.

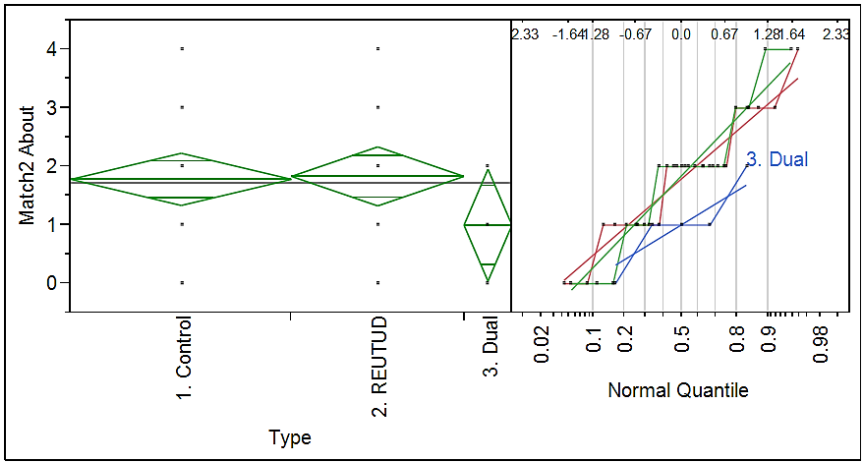

Figure 14. Similar cultural tendencies, showing no statistical distinction with Prob>F 0.2847.

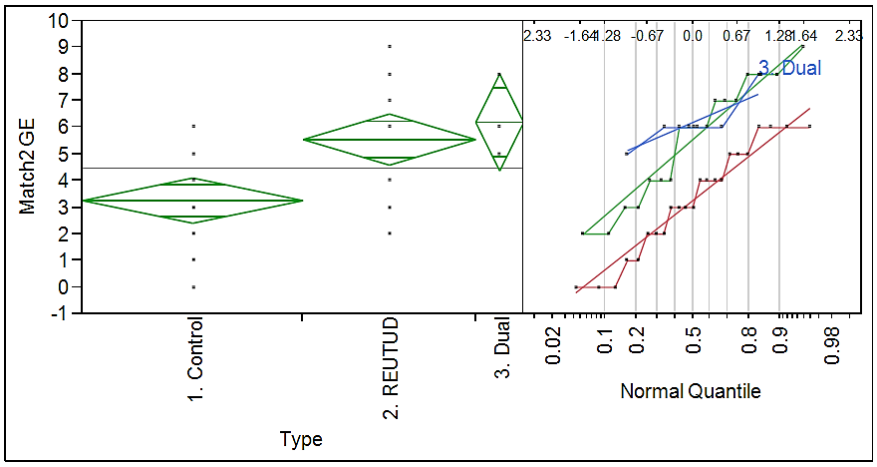

Figure 15. German cultural tendencies, showing a very strong statistical difference between the groups with the populations stratifying based upon time abroad, with a Prob>F 0.0008.

One of the founding questions of this research project was the observation described by Downey that students tend to stress similarity across cultures, while ignoring differences (Downey 2006). One gauge of this is the tendency of students to answer questions that culturally skew to either the USA or Germany with the neutral answer, "About the same." The domestic Control group used this neutral answer significantly more than the REUTUD students who spent a summer abroad, as shown in Figure 16.

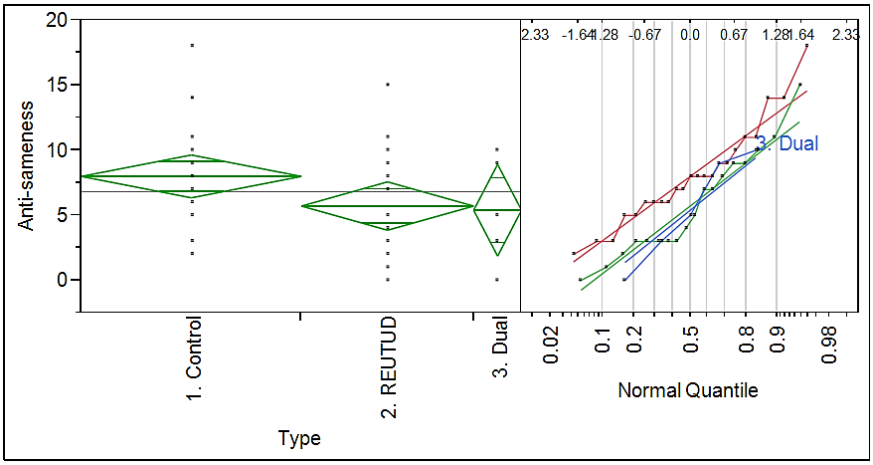

Figure 16. The ability of students to overcome sameness, as measured by the number of questions they answered incorrectly as "About the same," with Prob>F 0.1371. Given this format, a lower score indicates a greater appreciation of difference. When the large the control and REUTUD groups are compared, the significance increases, with Prob > F 0.0702, showing a statistically significant difference between the groups.

These results show significant differences between the student groups, with students who spent more time abroad tending to perform significantly better. The student groups performed

similarly well on the cultural questions on the USA, but substantially diverged on the German cultural questions. While this serves to confirm that students who study abroad are measurably different, their scores in all sections of the GCS remained low. This may indicate that these students still have more to learn about U.S. and German history and culture, which the authors expect to be true.

3.3.5 Results of the GCAA

The low response rates of the students taking the GCAA, 23% across all groups, allowed only for comparison of the domestic Control group and the short-term study abroad REUTUD group, and with limited significance. Overall, the Internal and External readiness scores for both the Control and the REUTUD groups were found to be equivalent and without distinction between these two groups.

Within the individual sections that comprise the Internal and External Readiness scores, only two of the eight sections show statistically significant differences between the two study groups. The REUTUD group was found to score higher in the "Willing to Take Risks" Internal score, and the "Globally Aware" External score than the Control group, as shown in Table 10. It is reasonable that the study abroad group exhibit a greater inclination to risk-taking and broader understanding of the world than their domestic counterparts.

While the scores in these two categories are statistically significant, their overall meaning is unknown. As GLE, the makers of the GCAA, do not provide researchers with their proprietary developmental scale, the impact of a 5 or 10 point difference on the competency of these students is unknown.

Table 10. Summary of the GCAA datasets for Internal and External Readiness, with the two statistically significant results highlighted. These eight sub-sections are each scored on a 0-100 point scale. (GCAA 2011).

Internal Readiness Components					
	Control (10)		REUTUD (12)		Significant difference
	Mean	Std. Dev	Mean	Std. Dev	
Self-Aware	76.6	5.0	79.5	8.0	none
Willing to Take Risks	75.9	5.7	81.8	5.2	$p < 0.05$
Open-Minded	74.8	8.4	78.3	19.2	none
Perceptive and Respectful of Diversity	71.9	8.9	73.5	16.7	none

External Readiness Components					
	Control (10)		REUTUD (12)		Significant difference
	Mean	Std. Dev	Mean	Std. Dev	
Globally Aware	55.0	11.0	65.9	10.0	$p < 0.05$
Knowledgeable about World History	47.8	22.8	46.1	19.4	none
Interculturally Competent	66.4	14.5	73.2	11.5	none
Effective Across Cultures	79.5	10.4	78.6	10.4	none

3.3.6 Comparison between the GCS and GCAA

It is noteworthy that the GCAA was unable to distinguish between the domestic and education abroad cohorts on the other six components of Hunter's Global Competence Model. This could have been due to one of several reasons, including a distinguished Control group, low aggregate response rates, low impact of the study abroad program on the REUTUD students, or low resolution of the GCAA.

In contrast, the GCS was able to distinguish between the three student groups using questions related to factual knowledge about specific countries, in addition to cultural tendencies. As is common in education abroad, few students participate, and fewer still complete the assessment tools. Because of this, the GCS offered insight into the advantage the Dual degree students possess over the REUTUD and Control groups. In contrast, the GCAA was unable to provide a meaningful conclusion about these populations at least in part because too few students were willing to complete the assessment.

While the GCS is targeted to assess understanding of individual countries, the GCAA investigates eight regions at once: North America, Latin America and the Caribbean, Europe, Africa, Middle East, North Asia, Southeast Asia, and Oceania. As most education abroad

programs do not extend beyond the borders of one region, the GCAA appears to be fundamentally ill fitted for evaluating the growth in global competence among education abroad students.

It is important to note that the GCS, while providing substantially more information in a shorter format, is country-specific. By design, the GCAA is comprehensive and addresses the eight key areas that Hunter discovered as critical to global competency (GCAA 2011). This distinction is fundamental to this work, as the authors believe that growth in global competency must follow a measureable pathway. It is unreasonable to expect that most students will ever attain full global competency, or the ability to work effectively with anyone, from anywhere, and being mindful of all cultural cues. However, this limitation does not prevent them from having significantly greater competence in working in or with certain countries. This pedagogical difference forms the foundation of the GCS.

3.4 Limitations

This study suggests that there is a measureable difference in global competency between students who study domestically and those who engage in education abroad experiences. However, the small sample size and low participation rate from the Control population limit confidence in the study. The selection of the Control population was based on the need for a reasonably matched domestic counterpart to the short-term abroad REUTUD group. Based on demographic information collected along with the GCS, nearly all members of the Control group (before pooling with the REUVT participants) had international experience, ranging from short vacations to being born in a country other than the USA. While this should add an unanticipated advantage to the domestic Control group, it serves to further support the strength of the GCS, which detected differences between the short-term abroad REUTUD group and this unexpectedly globally experienced baseline group across multiple categories. However, this enhanced control group limits our understanding of what would count as general U.S. engineering students.

Additionally, these tools were deployed after the short-term abroad students (REUTUD) had repatriated, but during the term of long-term abroad students (Dual). This would likely underemphasize the difference between these groups, but was a necessary tradeoff to deploy these tools in a timely fashion. Regardless, the GCS still shows appreciable upward trends between program duration and global competence.

In addition, there is a need to scrutinize further the importance and construction of the questions in the GCS, to validate that this tool is measuring differences important to the development of global engineers. This could be supplemented further by expanding the pool of

questions and deploying them in the more traditional pre-experience/post-experience format to directly assess growth from different education abroad formats.

Finally, as the GCAA was administered after students completed the GCS, a reasonable response rate for this tool remains unknown. With small education abroad cohorts, limited access to detailed background information, and limited time for extensive interaction and interviews with the individual students, response rate is a critical criterion for efficient and effective assessment.

3.5 Conclusions

The first iteration of the GCS shows its value in assessing growth in global competence and in comparing the outcomes of various study abroad formats. The GCS was able to detect differences between three student populations, across multiple categories of questions concerning the USA and Germany. Though limited in scope, the GCS provides objective measure suggesting significant student growth in two education abroad formats.

While the GCAA is a validated tool, its use for determining student growth through education abroad program is problematic for several reasons. First, the long duration of the assessment hinders high response rates, limiting the significance of these studies. Additionally, the expense and the time and effort required to deploy the GCAA is significant. Taken together, these two factors will likely limit its use with education abroad programs.

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Chapter 4

Predicting Team Performance: Teamology in a Global Context

This chapter outlines the theory of teamology and validates it in a global context for dyadic teams. It first reviews the development and application of the theory of teamology, which is a method of composing high-performance engineering project teams using personality diversity and functional ability. Next, it describes an experiment involving global teams, and provides strong indication that the teamology method is able to predict team performance. This chapter appears in the format in which it was prepared for review in the *Journal of Mechanical Design*.

Predicting Team Performance: Teamology in a Global Context

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Abstract

The psychological composition of a team has a significant impact on the effectiveness of a team and can predict team success. Teaming is essential when performing complex engineering work, and there is a need for understanding how to build better teams. Teamology addresses this need. It uses both personality diversity and functional requirements to construct teams that are more innovative. Previous work has shown that teamology is effective for medium-size domestic teams. This paper evaluates the applicability of teamology for global two-person (dyadic) teams, with four engineering teams working in Germany for eight weeks serving as the focus of this study. Each team consisted of one U.S. undergraduate student and one German graduate mentor, selected based upon traditional criteria, including past academic performance, academic level, experience, and project preference. Following the completion of their project, the students and mentors rated the performance and cohesion of their team, and completed the teamology questionnaire. The questionnaire is an abbreviated personality profile used for mapping team personality diversity. The results confirm that global dyadic teams with greater diversity in how they collect information perform better ($r = 0.87$). Likewise, the results confirm that global teams with greater diversity in decision-making were more cohesive ($r = 0.97$). These results mirror those of larger domestic teams, and therefore teamology should be useful for composing significantly more effective small global teams.

Keywords: collaborative design; design teams; design education; global; innovation

4.1 Introduction

As we witness the increasing pressure of globalization, much attention has been placed on creating high-value, innovative technologies that are difficult to replicate. Because teams have the capacity to perform work faster and more creatively than individual contributors do, they are a reality across most industries and universities, and have become the workhorse of modern engineering design (Lussier 2007, Jones 2007, Wilde 2010). Within the academy, modern teams outperform individuals in the creation of knowledge as measured by production of citations and patents (Wuchty 2011).

Despite these advantages, teams generally fail to deliver on their full potential. Teams encounter challenges when coordinating efforts, maintaining focus and motivation, and making informed decisions (Jones 2007, Hackman 2002). For a team to excel, Hackman found that a team requires a dissident, a naysayer who challenges the team to examine assumptions and provides alternative perspective. However, teams are known to make and hold their members to norms, which tend to increase the cohesiveness of the team and inadvertently quell dissent. To function effectively, teams must balance dissent with cohesiveness gained in the norming process (Lussier 2007, Jones 2007, Hackman 2002).

To this end, Wilde found that the careful arrangement of personality diversity on a team dramatically improves the output of a common pool of candidates, and can be used to quickly build teams that are considerably more innovative (Wilde 2009b, Wilde 2010). This allows for the purposeful inclusion of dissidents on a team, with predictable improvements in performance. The technique can also be used to foster cohesion, which helps a team ride out difficulties.

This paper presents a small-sample validation and expansion of the novel approach to developing high-performance teams developed by Wilde. National Science Foundation Research Experiences for Undergraduates (REU) global dyadic teams serve as a test bed for determining the relationship between team performance and the personality diversity within a team. These dyadic teams performed two-month long research projects at Technische Universität Darmstadt (TUD), Germany, and completed Wilde's short teamology questionnaire to identify the number of Perception and Judgment cognitive roles on each team.

The results of this study present a strong upward correlation between the number of team Perception roles (information collection) and team performance ($r = 0.87$) and the number of team Judgment roles (decision-making) and team cohesion ($r = 0.97$). As companies and academia continue to rely on teams to solve complex problems, teamology can dramatically improve the intrinsic effectiveness of teams at the systems level by assembling teams based upon both functional need and cognitive mode diversity. Teamology could be used to build stronger teams to address critical priorities, ensure desired performance, reduce team size, or prevent low-

performance teams from being formed. Furthermore, as dyadic relationships serve as the operational unit of larger teams and shape how teams interact and succeed, this study may serve a broader audience beyond its original scope (Hackman 2002, Smith 2008).

4.1.1 Teamology

In his drive to improve student team performance, now professor emeritus Douglass J. Wilde of Stanford University began exploring methods of composing better teams. His efforts brought him to the Gough Creativity Index, a quantification of creativity, and Belbin, whose work identified roles that successful teams possessed and that low performance teams lacked (Wilde 2004). By combining this framework with Jungian psychology and the Myers-Briggs Typology Index (MBTI), Wilde began to experiment with the construction of more effective teams (Wilde 1999). Recognizing that Jung's theory could identify how individuals collect information and make decisions, summarized as cognitive modes, Wilde sought to determine how different cognitive modes affected team performance. Wilde was able to develop a method to quantify the cognitive mode theory created by Jung nearly a century earlier, which he named "teamology."

Teamology works by splitting the span of human personalities into two domains, one for collecting information and one for making decisions. This can be more easily visualized in the cognitive role maps shown in Figure 17. The goal of teamology is to cover all sixteen cognitive roles (8 cognitive modes) on each team, thereby providing the team with the fullest range of thinking abilities, as outlined in Table 11. This provides a team with the full range of human cognition, a condition identified by Hackman and Wilde to enhance creativity (Hackman 2002, Wilde 2010).

Those familiar with the MBTI will recognize the core types, Extrovert (E), Introvert (I), Sensing (S), Intuition (N), Thinking (T), and Feeling (F), represented on these axes, with the Perception and Judgment domains accounted as the decoupled coordinate systems. The decoupling process is discussed in Wilde's most recent work (Wilde 2011a, Wilde 2011b).

Table 11. Overview of Wilde's work combining Jung's cognitive mode theory and Belbin's role theory, with key descriptions of the individual roles. Seeding teams with individuals most highly ranked in the two highlighted modes, *ne* and *fe*, helped Wilde increase the number of Stanford teams winning national awards by 2-3 times prior years. A team covering all sixteen roles would satisfy the teamology criteria and be expected to offer superior performance. Descriptions quoted from (Wilde 2009b).

Wilde's decoupling of the Jungian cognitive modes					Wilde's cognitive roles		
Domain	Attitudes		Modes	Description	Roles		Description
Information Collection (Perception)	Extraversion	Sensing	se	Discovers new ideas and phenomena by direct experience	1. Tester	*Es*	Pushes performance envelope hands-on
					2. Prototyper	*eS*	Builds models and prototypes
		Intuition	ne	Rearranges known concepts into novel systems	3. Entrepreneur	*En*	Explores and promotes new products and methods
					4. Innovator	*eN*	Synthesizes new products by component modification
	Introversion	Sensing	si	Physically self-aware, values practice and known technique	5. Investigator	*iS*	Gets facts and know-how about prior experience
					6. Inspector	*Is*	Detects errors and enforces specifications
		Intuition	ni	Prophetic, guided by inner fantasies and visions	7. Visionary	*iN*	Visualizes unusual design forms and uses
					8. Strategist	*In*	Speculates on project and product future
Decision-Making (Judgment)	Extraversion	Thinking	te	Efficiently manages resources, decisive, imposes structure	9. Coordinator	*Et*	Focuses activities to save time and effort
					10. Methodologist	*eT*	Sets deadlines, modifies procedures and breaks bottlenecks
		Feeling	fe	Expressive, tactful builder of group morale	11. Diplomat	*Ef*	Harmonizes team, client and consumer
					12. Conciliator	*eF*	Detects and resolves interpersonal issues
	Introversion	Thinking	ti	Rationally improves quantitative performance	13. Specialist	*iT*	Analyzes performance and efficiency
					14. Analyst/ Reviewer	*It*	Compares performance to goals and standards
		Feeling	fi	Uses personal values to distinguish good/bad	15. Needfinder	*iF*	Evaluates human factors and consumer issues
					16. Critiquer	*If*	Addresses aesthetic and moral issues

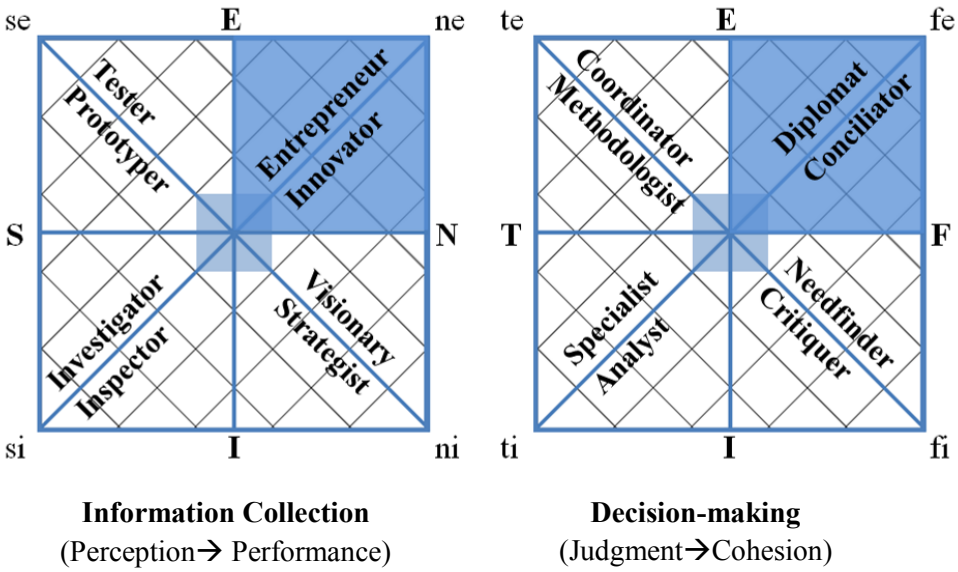

Figure 17. Wilde's cognitive role maps split the Jungian cognitive modes into two domains calibrated to his teamology questionnaire. The eight modes represented as quadrants are further divided into two functional roles each, shown as the named triangular sections, for a possible total of 16 roles per team. The small shaded square at the center of each map is below the minimum threshold for preference. The large shaded square distinguishes the seeding mode, *ne* or *fe*, that Wilde claims improved national Lincoln Award winnings. Based on (Wilde 2009a) and (Wilde 2011a).

While these maps identify role preference, Wilde advocates that a team cover every role to enhance performance, even if this requires members to take on roles outside of their psychological preferences (Wilde 2009b, Wilde 2011b). As most individuals naturally prefer and excel at some roles over others, Wilde taught his teams about cognitive roles and had members attempt to cover these missing thought patterns. Voluntary role reaching allows individuals on a team to purposefully cover missing modes and thereby enhance their aggregate ability to collect information or make decisions (Wilde 2009b).

In developing his teamology method, Wilde documents first a doubling, and later a tripling, of the number of Stanford graduate level teams that won awards through the national Lincoln Foundation Awards, as shown in Figure 18. Not only did the teams assembled using cognitive mode theory take more prizes on average, they took substantially more top awards than the previous decade of teams. During the first year of applying personality diversity, Stanford teams took two and a half times as many awards as their previous record, winning 10 out of the 12 awards with dyadic teams by maximizing differences in personality (Wilde 2009b). Wilde later created a heuristic to seed teams with students who ranked highest in the *ne* mode score (Perception), and the highest ranked *fe* students as well (Perception and Judgment). From there, students self-assembled onto seeded teams of approximately four students. Interestingly, Wilde observed early on that for each additional role covered by a team they became dramatically more

innovative, and on average won a higher level prize. This trend was later confirmed by the work of Stanfill at the University of Florida (Wilde 2009b).

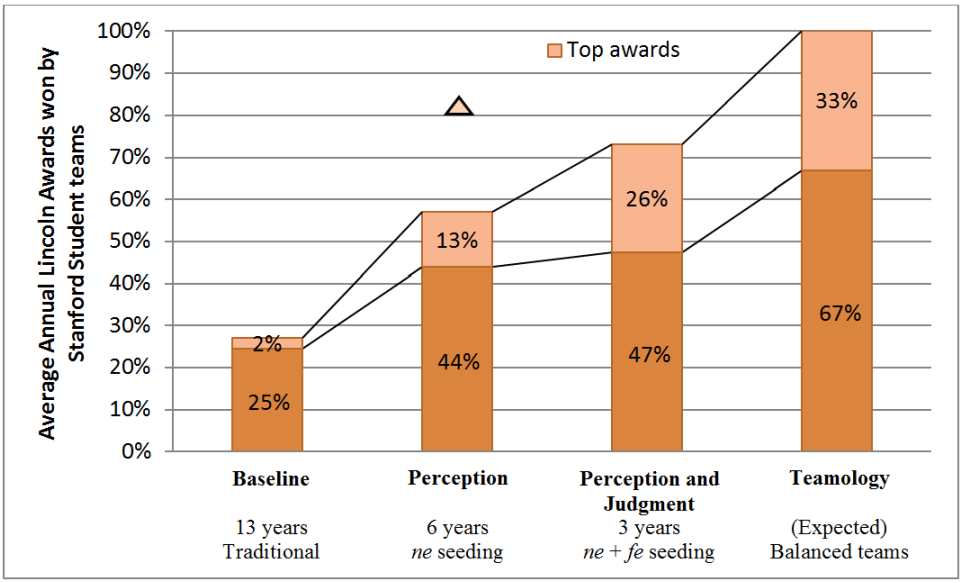

Figure 18. Results from the application of cognitive mode theory to Stanford graduate-level design teams. This shows first a doubling and then tripling of the number of students winning awards relative to the baseline years before cognitive mode matching, and a dramatic increase in the number of the most innovative teams, those winning top awards (Silver, Gold, or Best). The first year personality diversity was used to form teams, dyads won 83% of the awards given that year, shown as a triangle. Based on (Wilde 1997), (Wilde 2004) and (Wilde 2009b).

Given this dramatic improvement, Wilde continued to refine his understanding and developed teamology. Teamology uses the preceding advancements of seeding, and uses a heuristic to assign students to teams in order to cover all eight cognitive modes and maximize personality diversity. Additional studies were undertaken to evaluate teamology teams relative to teams assembled using more traditional matching methods, such as self-assembly and cross-functionality in course projects or short team activities. During a confirmation studies, Delson observed that teams assembled by the teamology method were more creative, yet felt less cohesive (Wilde 2009b). Mitani et al. observed that teamology teams produced better results in short-term projects at Maruzen Industry in Japan, and the method is useful in creating balanced teams or teams tailored for a specific task, such as ideation or execution. Additionally, Mitani et al. noted that personality types do not reliably track job titles, despite similar responsibilities, and individuals can temporarily change roles depending on their responsibilities to the team (Mitani 2009). These studies appear to validate Wilde's predictions for improving team performance with teamology (Wilde 2009b).

4.1.2 Observations

There are several conclusions that can be drawn from Wilde's numerous publications and remarkable improvements to his cognitive mode method. The results of applying cognitive mode theory to assemble award-winning teams over a decade provide compelling evidence for the advantages of using the teamology method for assembling teams that are more effective. Therefore, the most obvious conclusion is that teamology, and Wilde's refinement of the underlying cognitive mode theory, produces teams that are indeed more innovative.

Interestingly, adding a single role to a team was associated with a substantial improvement in creativity by both Wilde and Stanfill (Wilde 2009b). This suggests that not only are the differences between high and low performance teams bridgeable, but that small changes in team composition could have a dramatic impact on team performance. Also noteworthy is that in the first year that cognitive mode theory was used to assemble teams by maximizing MBTI differences, unusually small dyadic teams took 83% of the national awards given that year. On average, these two-person teams outperformed the larger teams that followed in later years. Additionally, Delson observed that teams with strong personality diversity performed better and yet felt less cohesive than traditionally designed control teams (Wilde 2009b). It is also implied that most students who join the class are capable of working effectively on a team.

However, the application of teamology and the preceding methods were not the only changes that occurred during the years of steady improvement and that may have influenced team performance. The importance of group-efficacy, coupled with Wilde's understanding of teambuilding and the award process, and structural changes to the course, were not tested separately from the purposeful application of personality diversity. Also, the importance of voluntary role-reaching is questionable. While Mitani observed one participant take on roles outside of his psychological preference, it remains to be shown whether this elected position can override one's more enduring personality preference in the long-term and when under duress (Mitani 2009).

Importantly, Wilde highlights the work of Bandura related to self-efficacy and group-efficacy, and uses this as the basis for initial team meetings (Bandura 1997, Wilde 2009b). As such, these teams likely begin their group projects with a better understanding of their capabilities, and believe that they can perform well together. When coupled with the teamology matching process, this could mimic self-fulfilling prophecy.

Additionally, it is likely that Wilde has grown in understanding and teaching the design process, and in his knowledge of the Lincoln Awards program. As the Lincoln Awards serve as his key metric for evaluating the importance of personality diversity, this continuity could influence how teams were formed, offered guidance, or reviewed prior to submitting their work.

Furthermore, Stanford University likely underwent substantial changes not reflected in the teamology data over the two decades of Wilde's study, including dramatic advancements in computing, and changes in course faculty. It is also likely that the success of past teams enticed better-qualified students to join the course over the same period that team size was expanding. This would provide later teams with additional opportunities to distribute the workload, or explore more time-intensive avenues.

Although Wilde notes in *Teamology* that team performance returned to pre-cognitive mode levels when he was on sabbatical as proof that teamology works, his absence does not address all of these potentially confounding factors (Wilde 2009b).

4.2 Problem Statement

While much of Wilde's work has sought to use teamology and preceding methods to build higher performing teams, it reasons that the teamology method should work in reverse and without the confounding factors outline above. When applied to teams assembled using traditional criteria, the number of cognitive roles on a team should predict team outcomes, which is the primary focus of this paper.

Can the cognitive role theory of teamology be used to predict performance and cohesion in small teams, and is it operational across cultures?

4.3 Evaluating teamology using global teams

To evaluate the accuracy of Wilde's cognitive role theory, this study uses information from team projects performed through a joint transatlantic National Science Foundation Research Experiences for Undergraduates (REU) program in automotive technologies at Virginia Tech and Technische Universität Darmstadt (VT-TUD). These transatlantic research projects paired a U.S. undergraduate student with a German graduate mentor. The U.S. students were selected for the VT-TUD summer REU program using traditional methods, including academic performance, academic level, experience, perceived fit for the position, and without regard for cognitive mode theory. The students and their mentors worked together for two months in Germany on research projects related to automotive technology. This program was highly competitive, with an average acceptance rate of 22% over the first three years.

As part of a larger research project assessing global competency, students and mentors completed an online survey that included Wilde's teamology questionnaire to determine their primary cognitive roles (Wilde 2011a). Additionally, students rated their partnership on how they perceived their experience and how cohesive the team was, as shown in Figure 19. Mentors

evaluated the outcome and cohesion of their team during personal interviews, using the same rating scale.

Question 1: How would you rate your experience with your research experience or study abroad?

0 = Not Applicable
1 = Poor
2 = Below average
3 = Above average
4 = Excellent (better than expected)

Question 2: Relative to past team experiences, how cohesive was your REU or study abroad team?

0 = Not Applicable
1 = Poor
2 = Below average
3 = Above average
4 = Excellent (better than expected)

Figure 19. U.S. REU participants were asked Questions 1 and 2 to assess the efficacy of the Teamology method.

In order to ease quantification of this method, three of Wilde's concepts were modified. First, mode reaching was ignored because it cannot be measured with the teamology questionnaire and therefore cannot be used to assess efficacy of the underlying cognitive theory. That is, if every team can simply stretch to meet the cognitive needs of the team, all teams could perform equally well. Additionally, participants in this study were not introduced to concept of cognitive modes and therefore lacked the opportunity to systematically cover missing modes. Therefore, it was assumed that the participants in this study would only exhibit their primary roles.

Second, each of the sixteen cognitive roles were counted as discrete, and satisfied if an individual's role score fell within the region and beyond the minimum threshold for preference. Roles were used instead of modes to extend the resolution of the mapping instrument, and discretized to allow for simple quantification.

Lastly, individuals with scores evenly straddling two roles were counted as having two primary roles. This was done as a way of connecting with the core reasoning behind Wilde's preference for cognitive mode reaching, that people can exhibit broader thinking abilities, in a rule-based manner. Beyond simplifying the process, these changes were necessary in order to evaluate the underlying theory of the teamology method, without the heuristic process used at Stanford.

4.3.1 Results and Discussion

The responses of these teams offer an indication that they reflect a normal expectation for teams, summarized in Figure 20. Despite benefiting from high selectivity and motivation, these teams exhibit no truly remarkable enhancement in result or cohesion than past teaming experiences.

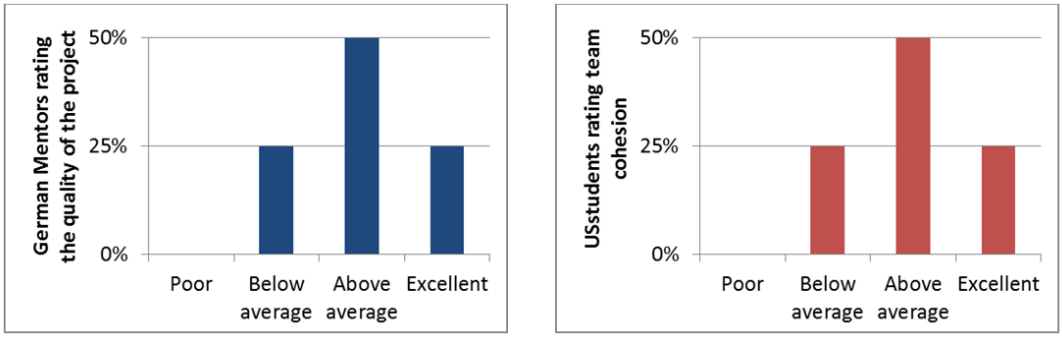

Figure 20. An overview of the ratings of the VT-TUD collaborative engineering projects, showing trends that meet reasonable expectations for these teams. Of note is that the performance of a team is not always related to the cohesion of its members, as the team with the best performance in this study experienced the lowest cohesion.

Next, role maps for the four VT-TUD teams were generated using the modified teamology processing outlined above, and are shown in Figure 21. Within these dyadic teams, the number of Perception and Judgment roles ranged from one to four, which in turn tracks with the performance and cohesion of the team respectively. There appears to be a relationship between an "excellent" rating and having four roles covered, as both Team 1 and Team 2 exhibit, while no other teams achieved this rating.

Additionally, teams with singular roles appear to perform better when both members exhibit some preference for the role. This can be seen by comparing Team 4 with Team 2 and Team 3, which each have one domain with only one role covered, and yet have different outcomes for that domain. When judged on performance alone, it appears that the mentor on Team 3 provides little benefit to the team, and may be better utilized as an individual contributor.

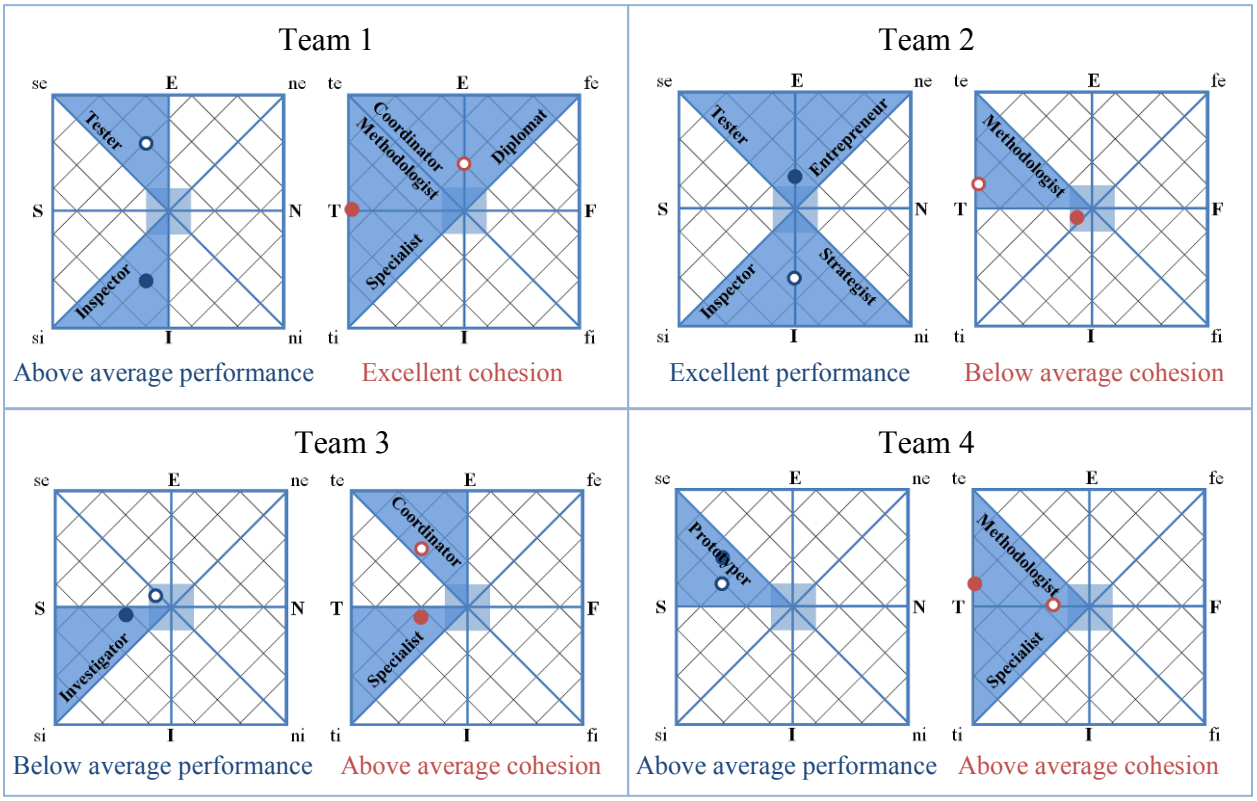

Figure 21. Teamology role maps for the four U.S.-German teams, with the U.S. undergraduate student represented as a solid circle, and the German graduate mentor as a hollow circle. The circles are color-coded to show Perception roles that impact performance in blue, and Judgment roles that affect cohesion in red.

When analyzed through the lens of teamology, the data show strong correlation between personality diversity and team performance and cohesion, consistent with Wilde's work. The German graduate students who serve as mentors for the REU projects have experience in evaluating projects, which makes their assessment of project outcome more rigorous and reliable. As shown in Figure 22, the correlation between the Perception roles possessed by a team and the Result of the project as assessed by the German mentor is high ($r = 0.87$). Also, the highest performance team, Team 2, was the only one with a *ne* mode activated (*En*). This further echoes Wilde's six years of Perception data, as both show a strong upward trend (Wilde 2009b).

While Wilde expects a correlation between the number of Judgment roles and team Cohesion, none appears to exist with the German mentors. This is likely due to a lack of understanding of what the term "cohesion" on a team meant, which was a source of confusion during the mentor interviews.

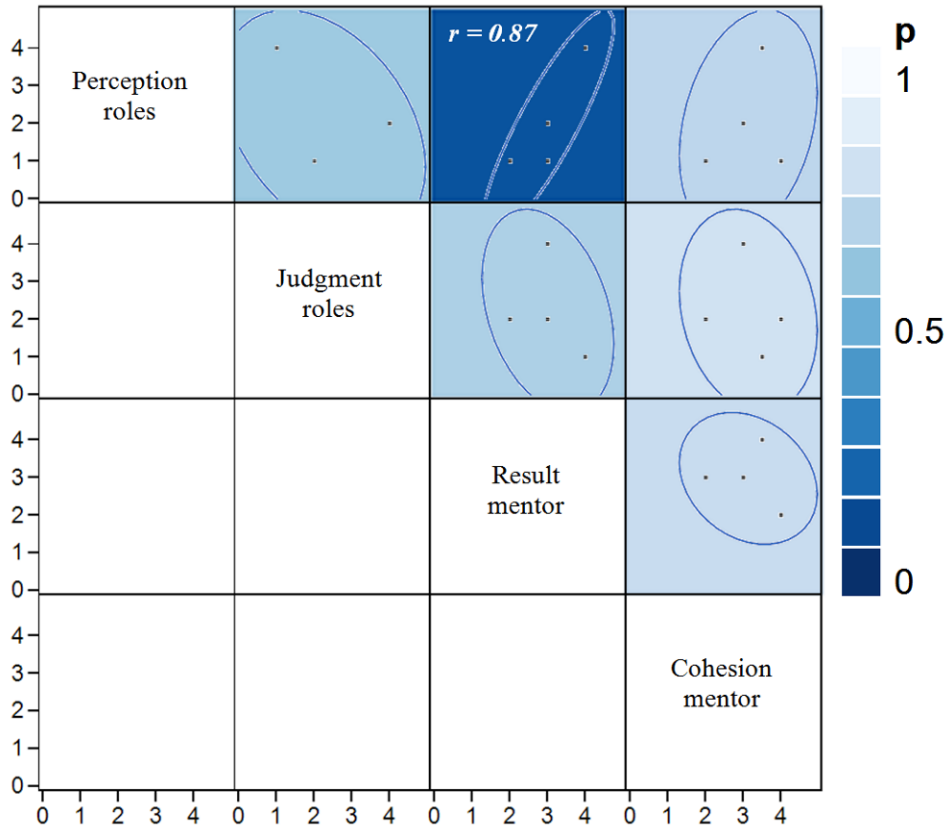

Figure 22. Multivariate correlation showing a strong correlation between the number of Perception roles within a team and the performance of the team, as rated by the German mentor, with r = 0.87. A low p value indicates a strong correlation, shown with a darker color.

In contrast with the results from their German mentors, it is not surprising, the U.S. undergraduate students consistently rated the experience of performing research abroad highly (mean = 3.75/4), which shows little correlation with the number of team personality roles, as shown in Figure 23. However, the number of Judgment modes within a team was strongly correlated with the cohesion of the team (r = 0.97), which is mentioned by Wilde as explored by Delson (Wilde 2009b). Also, the team with the greatest cohesion was the only team to have a *fe* mode activated (*Ef*).When combined with the data from the German mentors, these two strong correlations offer preliminary empirical validation of Wilde's teamology work, and the importance of the *ne* and *fe* modes.

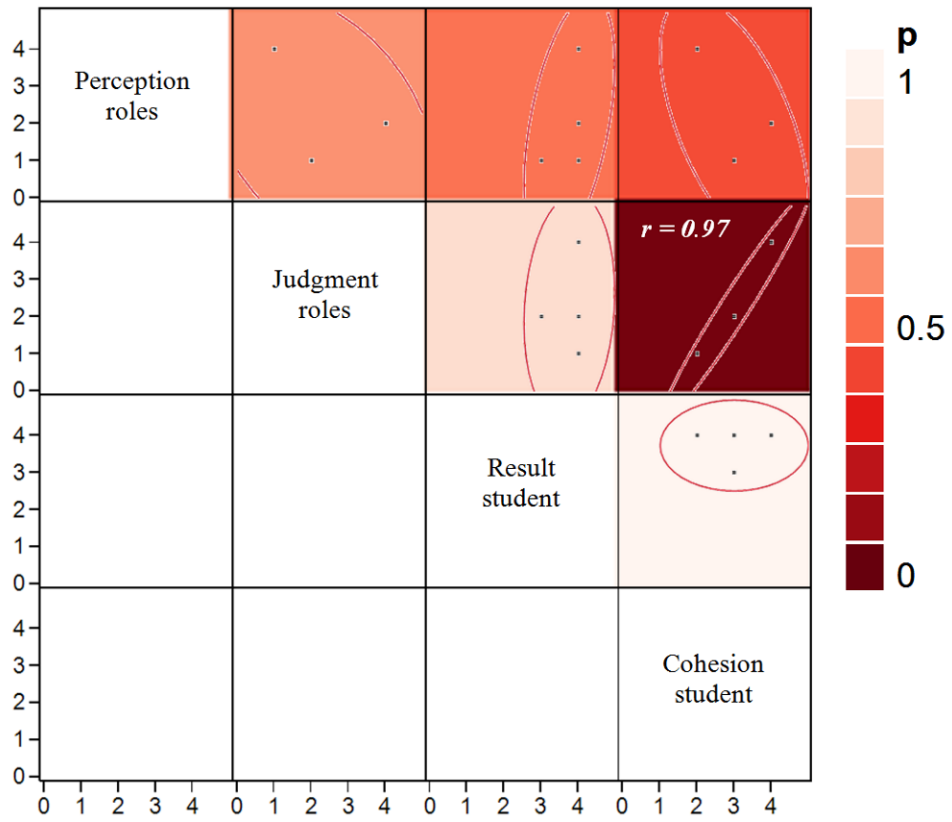

Figure 23. Multivariate correlation showing a strong correlation between the number of Judgment roles within a team and the cohesion of the team, as rated by the U.S. student, with r = 0.97. A low p value indicates a strong correlation, shown with a darker color.

More generically, there appears to be a relationship between the number of roles and the outcome of the team in either the quality of their result or the cohesion of the team, as outlined in Figure 24. While preliminary in nature, this information could be used to produce a mathematical model of the expected improvement of a team based upon the number of roles they possess. Since each team provides two data points, one for Perception and one for Judgment roles, this approach could enhance the impact of each team in the study.

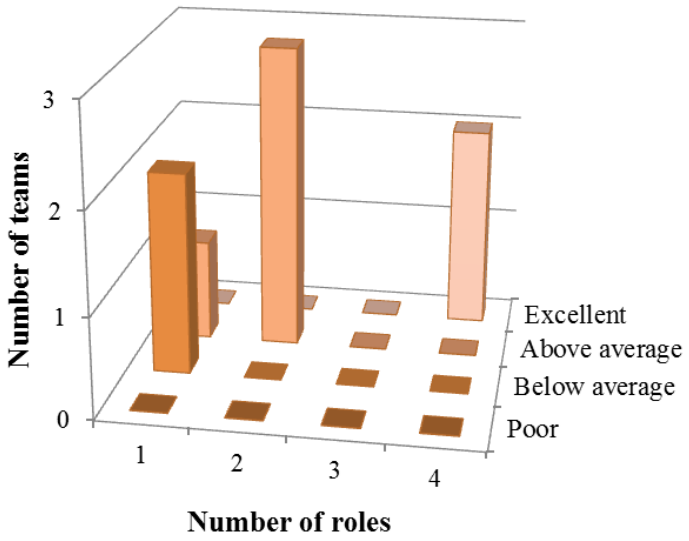

Figure 24. This graph shows what appears to be a nearly discrete relationship between the number of roles on a team and the outcome of that team, across both the Perception and Judgment domains. The outlier of 1 role and Above average outcome came from Team 4, where both the student and the mentor shared preference for that role.

4.3.2 Limitations

This study shows strong indications that Wilde's theory is valid and applicable to small global research teams. Team performance closely tracks the number of perception roles, and team cohesion closely tracks the number of judgment roles. However, the small sample size limits the evaluation of Wilde's full theory of maximizing Perception and Judgment modes, and the importance of mode reaching for ideal performance.

Additionally, all students in this study were highly motivated individuals evaluated for potential fit based upon area of interest and past performance in school for this highly competitive global research opportunity. As such, they do not represent a normal population distribution and the general applicability of teamology is unknown. Also, as all of the participants were mechanical engineering students of similar age, and the effectiveness of teamology when used on cross-functional, or the increasingly important trans-generational, teams remains unknown. Moreover, this study is limited to teams with members from Western cultures, and the importance of teamology to other cultures was not addressed.

4.4 Conclusions

This study presents a relationship between cognitive mode diversity and team performance and cohesion on global dyadic teams, and provides further confirmation of the teamology process separate from Wilde's work. The number of Perception roles was correlated

with team performance (r = 0.87) as rated by the German mentor, and Judgment roles was strongly correlated with team cohesion (r = 0.97) as rated by the U.S. undergraduate students. No other significant correlations were found, though the highest performing and most cohesive teams exhibited modes that Wilde found to be most critical, *ne* and *fe*. While strong correlation does not guarantee success, it does offer the possibility to improve average team performance.

While Wilde prefers balancing all teams in a classroom setting, it is conceivable that teamology could be used in industrial settings to develop intrinsically more creative teams to address critical priorities. Managers using teamology have the potential to predict team outcomes more consistently, focus limited human resources on critical priorities, and reduce team sizes, all while significantly enhancing team performance.

As the balancing of personality diversity appears to happen randomly without the teamology method, it is imperative that managers control this process and apply it to the most valuable projects, as with any other limited resource. This provides the opportunity to transform a poor performing team into one with good or even stellar performance, which could have significant economic impact. For instance, the design of Team 3 could have been modified, or even cancelled, rather than moving forward with team that was without the necessary cognitive diversity for high performance.

Although it is unlikely that the full benefit of teamology can be realized in dyads, this structure appears to offer the opportunity for significant performance improvement and important insights into the effective operation of teams. The simplified processing of teamology data offers substantial implications for future efforts to assemble teams for high performance and strong cohesion.

4.5 Future work

This research work is ongoing, and future work will include expanding the sample size of this study to further evaluate this method and allow for stronger statistical inferences to be drawn, with a focus on identifying key drivers of team performance. This will include evaluating the relative importance of *ne* and *fe* modes on team performance, which Wilde identifies as the seeds for his improved teams, and to test the sensitivity of the teamology questionnaire. Also of interest is the relative frequency of these critical modes within the mechanical engineering population, as measured by Wilde's tool.

As the teams in this study were dyads of one German mentor and one U.S. student, the total number of cognitive roles they can cover is limited to four Perception and four Judgment roles, as most individuals have between zero and two roles. This opens the question of whether a saturation point of cognitive roles or a continuum with the number of roles for high performance

exists, as some of Wilde's early work suggests (Wilde 2004). This could aid in determining minimum effective team size, while maximum team size could be constrained by logistical concerns. Also of interest would be to determine whether Wilde's teamology questionnaire could identify those individuals better suited for roles as individual contributors, such as the mentor on Team 3. In another setting, this would allow the student to be added to Team 1 or Team 4, likely increasing their team performance. Additionally, while Mitani et al. observed mode stretching in one individual, mode stretching deserves further attention as it offers great potential for balancing teams, but the enduring nature of personality may ultimately overwhelm this elected function (Mitani 2009). Moreover, the application of teamology to collaborations beyond those of Western and Asian nations remains unknown.

Furthermore, it is reasonable to conceive of an economic valuation of the teamology process, in addition to developing a mathematical model for predicting team improvement from increasing the number of cognitive roles available on a team. We expect the value of transforming a low performance team into an average performance team, or better still a high-performance team, to be significant. Moreover, the application of teamology to cross-functional, distributed global, or trans-generational teams was not explored in this work, and deserves further study.

Finally, the importance of dyadic relationships within a team may provide new insight into how teams interact, succeed, or fail, as outlined in Figure 25. This model shows a team as an assemblage of dyadic relationships between individuals, that shape the performance of the greater team, with each capable of maintaining their own interests. Of particular interest might be the application of teamology to teams with strong aggregate role numbers, but with a range of dyadic role numbers. This may help show which types of teams can rally and overcome interpersonal or knowledge weaknesses, and whether the strength of the weakest, average, or strongest dyadic links determines team success.

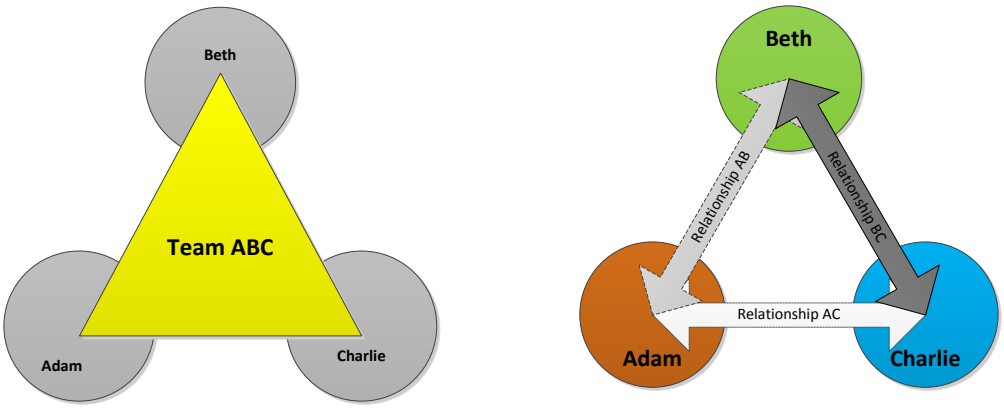

Figure 25. A common interpretation of a team, as superior to the individuals that make it up, and with singular vision (left). A proposed model of a team as an assemblage of individuals, with the strength of the dyadic relationships shown by the intensity of the two links (right).

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Chapter 5

Conclusions and Contributions

5.1 Conclusions

This thesis presents a new method of assessing student gains in global competency, in a quick and intuitive format. The GCS shows that students who have studied abroad are measurably different from their domestic counterparts in understanding home and host cultural cues. When compared with the commercially available GCAA, the GCS shows promise as an efficient and effective tool in assessing student growth.

Additionally, this education was able to validate the teamology method in a global context. Small research teams created using traditional matching methods, and their performance and cohesion closely track their aggregate personality diversity. Furthermore, this work includes a summary and simplification of Wilde's teamology work, and sheds new light on the importance of two-person teams (dyads).

5.2 Contributions

1. This research shows that education abroad students form a distinct population capable of recognizing foreign cultural cues and exhibit greater knowledge of both their home and host countries. It is also evident that longer term experiences provide greater benefit. It is unclear whether virtual collaborations provide an adequate opportunity to improve global competency.

2. This effort produced a new assessment tool, the GCS, which is effective and efficient at assessing student growth in understanding culture, and achieves high response rates with a short time to complete the assessment. As education abroad cohorts tend to be small, capturing more responses is critical to enable future comparative analysis of programs to enhance the global competency of engineering students.

3. This study presents the first statistically significant results from the GCAA, showing that domestic and short-term education abroad student groups are measurably different according to two out of Hunter's eight criteria for global competency. This provides validation for the findings of the GCS.

4. By analyzing traditionally designed teams through the lens of Wilde's work, this thesis suggests that teamology is an effective tool for assembling cross-cultural research teams. This is an important finding as Wilde's research on teamology suggests that small changes in team composition can have a significant impact on team outcomes.

5.3 Future work

1. This work serves as a successful prototype for studying global competency in engineering students and evaluating the teamology method, and there is a need to expand this work to increase the confidence in these conclusions.

2. Expanding the question base of the GCS would allow for the more common pre- and post-experience format of academic assessment, and allow for student gains in global competence to be tracked based on the type of experience and duration. Additionally, work needs to be done to evaluate the most effective questions and format to further streamline the assessment process.

3. With further development, the GCS could be tailored to assess additional countries as modules, which would aid in defining global competence as a developmental process beginning with one host country and moving outward.

4. There is a significant opportunity to better understand how teams function well and poorly by examining the often overlooked interpersonal psychological relations of team members, and there is a need to optimize the distribution of personality across program teams.

Appendix A: Global Competency Proficiency Scale

Score	GS Grades	Proficiency Level quoted from (NIH 2010)	Proficiency Level quoted from (Bird 2004)	Engineering Global Competency
5	15	Expert—recognized authority; "the 'go to' person"	Expert—Holistic recognition and intuition rather than rules. Framing and reframing strategies as they read; changing cues that others do not perceive or read.	
4	10-14	Advanced—applied theory. Can perform skill without assistance, and can coach others; "a person to ask"	Proficiency—Calculation and rational analysis seem to disappear, and unconscious, fluid, effortless performance begins to emerge.	
3	7-10/11	Intermediate—practical application. Can perform skill independently, with minimal assistance	Competence—Greater appreciation for task complexity. Recognition of larger set of cues and ability to focus on most important cues. Reliance on absolute rules begins to disappear; risk taking and complex trade-offs occur.	Swiss Consulting Group Downey Blumenthal Hunter Lohmann Parkinson
2	4-7	Novice—limited experience. Classroom experience, develop on-the-job	Advanced Beginner—Experience produces understanding that exceeds stated facts and rules	
1	1 -4	Fundamental Awareness—basic knowledge. Common knowledge, focus on learning	Novice—Rules are learned as absolutes	

References: (NIH 2010); (Bird 2004); (Swiss Consulting Group Global Competence Report 2002); (Downey 2006); (Blumenthal 2008); (Hunter 2006); (Lohmann 2006); (Parkinson 2009).

Appendix B: IRB Approval

VirginiaTech

Office of Research Compliance
Institutional Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24060
540/231-4606 Fax 540/231-0959
e-mail irb@vt.edu
Website: www.irb.vt.edu

MEMORANDUM

DATE: April 26, 2010

TO: Jan Helge Bøhn, Matthew Cobert

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires June 13, 2011)

PROTOCOL TITLE: Assessing Global Competency in Engineering Students

IRB NUMBER: 10-347

As of April 26, 2010, the Virginia Tech IRB Chair, Dr. David M. Moore, approved the new protocol for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at http://www.irb.vt.edu/pages/responsibilities.htm (please review before the commencement of your research).

PROTOCOL INFORMATION:
Approved as: **Expedited, under 45 CFR 46.110 category(ies) 6, 7**
Protocol Approval Date: **4/26/2010**
Protocol Expiration Date: **4/25/2011**
Continuing Review Due Date*: **4/11/2011**
*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:
Per federally regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals / work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Date*	OSP Number	Sponsor	Grant Comparison Conducted?
4/26/2010	06043609	NSF	yes on 4/26/2010

*Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.

cc: File

VirginiaTech

Office of Research Compliance
Institutional Review Board
2000 Kraft Drive, Suite 2000 (0497)
Blacksburg, Virginia 24060
540/231-4606 Fax 540/231-0959
e-mail irb@vt.edu
Website: www.irb.vt.edu

MEMORANDUM

DATE: April 6, 2011

TO: Jan Helge Bøhn, Matthew Cobert

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires October 26, 2013)

PROTOCOL TITLE: Assessing Global Competency in Engineering Students

IRB NUMBER: 10-347

Effective April 26, 2011, the Virginia Tech IRB Chair, Dr. David M. Moore, approved the continuation request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at http://www.irb.vt.edu/pages/responsibilities.htm (please review before the commencement of your research).

PROTOCOL INFORMATION:
Approved as: **Expedited, under 45 CFR 46.110 category(ies) 6, 7**
Protocol Approval Date: **4/26/2011 (protocol's initial approval date: 4/26/2010)**
Protocol Expiration Date: **4/25/2012**
Continuing Review Due Date*: **4/11/2012**
*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

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If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.

cc: File

Appendix C: Global Competence Survey (GCS)

Global Awareness Assessment (USA and Germany)

This first section is designed to evaluate your knowledge of important factual concepts critical to understanding the USA and Germany. As we are seeking to better understand students, please complete this survey on your own, and without consulting outside resources or the Internet.

United States of America (USA)

1. The capital of the USA is:
   Baltimore New York Richmond Washington, D.C. Not sure

2. America's main source of Gross Domestic Product (GDP) is:
   Agriculture Construction Industry Services Not sure

3. The fastest growing minority group in the USA are:
   Asians Blacks Latinos Pacific Islanders Not sure

4. The largest religious group in the USA are:
   Atheist Buddhists Christians Jews Hindu Muslims Not sure

5. Who is the current leader of the USA:
   Bush Clinton Obama Reagan Not sure

6. How many states does the USA have:
   48 49 50 51 52 Not sure

7. America was part of a coalition of allies in the Second World War, including all of the following except:
   Britain Sweden Canada USSR Not sure

8. The light bulb was invented by a:
   Edison Oppenheimer Tesla Westinghouse Not sure

9. Approximately how many people live in the USA (in millions):
   200 300 400 500 Not sure

Global Awareness Assessment (USA and Germany)

Federal Republic of Germany (Germany)

10. The capital of Germany is:
    Berlin Bonn Darmstadt Frankfurt Munich Not sure

11. Germany's main source of Gross Domestic Product (GDP) is:
    Agriculture Construction Industry Services Not sure

12. The largest immigrant group in Germany comes from:
    Poland Serbia Turkey India Not sure

13. The largest religious group in Germany are:
    Atheist Buddhists Christians Jews Hindu Muslims Not sure

14. Who is the current chancellor of Germany:
    Brant Merkel Schröeder Thatcher Not sure

15. How many states does Germany have:
    1 8 16 24 32 Not sure

16. After being decimated in the Second World War, much of Germany was rebuilt through which plan:
    Churchill Marshall Mitchell Potsdam Not sure

17. Moveable type was invented by:
    Luther Geiger Gutenberg Riemann Not sure

18. Approximately how many people live in Germany (in millions):
    40 80 120 160 Not sure

Culture Match – Part 1

This section is intended to test your understanding of cultural norms in the USA and Germany. As these are dominant images for the people who inhabit these countries, not all individuals will exhibit these predominant characteristics. However, recognizing patterns and testing assumptions is critical to developing an understanding and intuition about others. Please base your answers on what you believe to be the dominant force within each culture, and if unsure of an answer, please leave the question blank or answer "Not sure."

19. Americans tend to be patient
    T F Not sure

20. The USA is home to the largest national economy in the world
    T F Not sure

21. Americans tend to be quick to make decisions
    T F Not sure

22. Americans tend to prefer stable employment over rapid growth
    T F Not sure

23. The USA is the world's largest consumer of oil
    T F Not sure

24. Germans tend to be patient
    T F Not sure

25. Germany is home to the largest economy in Europe
    T F Not sure

26. Germans tend to be quick to make decisions
    T F Not sure

27. Germans tend to prefer stable employment over rapid growth
    T F Not sure

28. Germany is the world's second largest exporter of goods
    T F Not sure

Culture Match – Part 2

On average, which peoples are more likely to:	Americans	About equal	Germans
29. Expect a high degree of equality and opportunity		X	
30. Expect individual responsibility	X		
31. Maintain traditional gender roles in society		X	
32. Tolerate uncertainty and take calculated risks	X		
33. Seek instant gratification in lieu of generational change	X		
34. Be concerned about the risks of genetically modified (GM) foods			X
35. Expect "cradle-to-grave" solutions for all products			X
36. Expect meetings to start and end on-time		X	
37. Celebrate individual victories	X		
38. Expect group decisions to be based on consensus			X
39. Expect group decisions to be made by majority vote	X		
40. Have individuals with fluency in more than one language			X
41. Expect individuals have an opportunity to achieve social mobility		X	
42. In the workplace, privacy is key			X
43. Open displays of patriotism are the norm	X		
44. It is common to take work home at night to finish	X		
45. Individuals tend to live fast-paced, busy lives	X		
46. Expect relaxed workplace protocol and to use first names	X		
47. Titles are important and hard-earned			X
48. Expect to read dense manuals to gain knowledge			X
49. Come prepared to meetings, and ready to take action			X
50. Prefer achieving utility over seeking perfection	X		
51. Have mandatory annual vacations			X

Appendix D: Comma Delimited Data from the GCS

,I am at least 18 years of age. ,I have read the Consent Form and conditions of this project. I have had all my questions answered. I consent to having my interview recorded onto an encrypted system from which my responses will be transcribed and coded. I hereby acknowledge the above and give my voluntary consent and indicate my agreement by signing below or checking the box found on the first page of the GCS (below). ,The capital of the USA is:,America's main source of Gross Domestic Product (GDP) is: ,The fastest growing minority group in the USA are: ,The largest religious group in the USA are: ,Who is the current leader of the USA:,How many states does the USA have:,"America was part of a coalition of allies in the Second World War, including all of the following except: ",The light bulb was invented by a: ,Approximately how many people live in the USA (in millions):,The capital of Germany is:,Germany's main source of Gross Domestic Product (GDP) is: ,The largest immigrant group in Germany comes from: ,The largest religious group in Germany are:,Who is the current chancellor of Germany:,How many states does Germany have:,"After being decimated in the Second World War, much of Germany was rebuilt through which plan: ",Moveable type was invented by: ,Approximately how many people live in Germany (in millions): ,"Please base your answers on what you believe to be the dominant force within each culture, and if unsure of an answer, please leave the question blank or answer "Not sure."",,,,,,,,,"On average, which peoples are more likely to:",,,,,,,,,,,,,,,,,,,,,,
,Response,1. Americans tend to be patient,2. The USA is home to the largest national economy in the world,3. Americans tend to be quick to make decisions,4. Americans tend to prefer stable employment over rapid growth,5. The USA is the world's largest consumer of oil,6. Germans tend to be patient,7. Germany is home to the largest economy in Europe,8. Germans tend to be quick to make decisions,9. Germans tend to prefer stable employment over rapid growth,10. Germany is the world's second largest exporter of goods,"1. Expect a high degree of equality and opportunity","2. Expect individual responsibility","3. Maintain traditional gender roles in society","4. Tolerate uncertainty and take calculated risks","5. Seek instant gratification in lieu of generational change","6. Be concerned about the risks of genetically modified (GM) foods","7. Expect "cradle-to-grave" solutions for all products","8. Expect meetings to start and end on-time","9. Celebrate individual victories","10. Expect group decisions to be based on consensus","11. Expect group decisions to be made by majority vote","12. Have individuals with fluency in more than one language","13. Expect individuals have an opportunity to achieve social mobility","14. In the workplace, privacy is key","15. Open displays of patriotism are the norm","16. It is common to take work home at night to finish","17. Individuals tend to live fast-paced, busy lives","18. Expect relaxed workplace protocol and to use first names","19. Titles are important and hard-earned","20. Expect to read dense manuals to gain knowledge","21. Come prepared to meetings, and ready to take action","22. Prefer achieving utility over seeking perfection","23. Have mandatory annual vacations"

UGR1,Yes,Yes,"Washington,
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Appendix E: GCAA Report

Global Competence Aptitude Assessment® Group Report

for

Virginia Polytechnic Institute and State University
Department of Mechanical Engineering

23 July 2011

Prepared for:

Mr. Matthew J. Cobert
Dr. Jan Helge Bøhn

Prepared by:

Global Leadership Excellence, LLC
6666 Passer Road
Coopersburg, PA 18036

Background

The world today is very different from the world of yesterday. There is an increasing and relentless rate of change characterized by economic liberalization, capital market developments, demographic shifts, talent mobility, technological innovation and recognition that the culture of the Internet has made this world far more interdependent than ever before in the history of mankind. Global activities now have a very fluid character, one in which new demands have surfaced for employees. Some would refer to these as Twenty-first (21st) Century Skills; others have referred to employees as being Globally Competent. While much has been written about Twenty-first Century Skills, little has been written about Global Competence. There is not only a paucity of research on the subject, but until recently, there has been no accepted definition of the term Global Competence.

Consequently, in 1999 a research agenda was begun to explore the phenomenon of Global Competence. The fundamental research questions were (1) to define what Global Competence means, and (2) to identify the knowledge, skills, attitudes and experiences that were necessary to become Global Competent.

Following a research design that included using the Delphi method and survey methodology, numerous educators from across a wide array of academic institutions and executives from corporations around the world were asked for input on these research questions. Surprisingly, there was congruence in the feedback from this diverse population of participants in this research study that led to a consensus definition of Global Competence:

> "Having an open mind while actively seeking to understand cultural norms and expectations of others, and leveraging this gained knowledge to interact, communicate, and work effectively outside one's environment."

Additionally, the international team created a mosaic of the knowledge, skills, and attitudes that they all agreed were necessary for Global Competence. A Globally Competent individual is:

- Self-Aware
- Open-Minded
- Willing to Take Risks
- Perceptive and Respectful of Diversity
- Knowledgeable about World History
- Globally Aware
- Interculturally Competent
- Effective across Cultures

Global Competence Model™

The Global Competence Model™ was borne out of the research published in the article "What Does it Mean to be Globally Competent?" in the *Journal of Studies in International Education*, September 2006.

The Global Competence Model™ above is a visual representation of the knowledge, skills, and attitudes necessary for global competence. Beginning at the core is one's knowing oneself and how one fits into his or her own culture (Self-Aware). The darker green layer reflects how one approaches people and situations. The green sections of the model relate to the personal trait and attitudinal drivers of Global Competence, called **Internal Readiness Characteristics**.

The blue sections, which highlight one's acquired knowledge through education or life experience, represent the **External Readiness Characteristics**. The lighter blue ring represents the additional skills one typically acquires through formal and continuous education in subjects such as history, geography, and world cultures. The darker blue ring reflects the people skills one develops over life experience, and one's ability to apply the knowledge gained to personal interactions. This culmination of skills is shown as one modifies outward behavior (Intercultural Competence) and interacts collaboratively and successfully in cross-cultural situations (Effective Across Cultures).

The Global Competence Model™ illustrates how one gains these capacities over time, often adding new layers of ability. As one moves visually outwardly from the core to the outer rim of the model, the level of sophistication in one's abilities increases. For one to be globally competent, it is necessary to have strength in both the Internal Readiness and External Readiness characteristics, which would be demonstrated by ratings of *High Aptitude for Global Competence* in each of the two categories. Developing global competence is a life's journey and it takes time to hone each of the above skills.

Global Competence Aptitude Assessment®

Out of a need to put the research findings into a practical measure, Global Leadership Excellence, LLC created an objective online Assessment—the Global Competence Aptitude Assessment (GCAA)®. Due to the nature of the Global Competence Model™, different styles of questions were necessary to effectively evaluate Internal Readiness as well as External Readiness components. For that reason, the GCAA® is comprised of four distinct sections, each with a different question style. There is cross-referencing throughout the GCAA® as each of the eight components of Global Competence is evaluated from a variety of angles, using different styles of questions, and varying degrees of difficulty. The result is a more complete measure of Global Competence.

Additionally, the questions are based on regions around the world, with particular emphasis placed on those countries that make significant contributions to the world's population and economy. Those regions are itemized as:

North America
Latin America and the Caribbean
Europe
Africa
Middle East
North Asia
Southeast Asia
Oceania

GCAA® Deployment

The GCAA® was deployed to a total sample of 45 Mechanical Engineering students from Virginia Polytechnic Institute and State University (VT) in the United States and the Technische Universität Darmstadt (TUD) in Germany beginning in June 2010. The sample was divided into the following subsets:

1. Undergraduate Researcher in Mechanical Engineering (UGR)(control group)
2. Research Experiences for Undergraduates, Virginia Tech (REUVT)
3. Research Experiences for Undergraduates, TU Darmstadt - Short Term Study Abroad to TUD (REUTUD)
4. VT-TUD Dual BSME degree - Senior Year Abroad at TU Darmstadt (Dual BS)

Program	Number of Deployments	Number of Respondents	Response Rate (%)
UGR	11	4	36.4
REUVT	10	6	60.0
REUTUD	18	12	66.7
Dual BS	6	2	33.3
Total	45	24	53.3

Due to the small sample size and their common domestic only education programs, the UGR and the REUVT programs were combined and served as a control group.

It should be noted that the overall sample size was very small, which is important to consider when drawing conclusions, especially when reviewing the Dual BS group.

Internal Readiness Results

Internal Readiness			
		Score	
Group	Sample Size	Mean	Std. Dev.
UGR/REUVT	10	74.6	5.8
REUTUD	12	78.0	12.5
Dual BS	2	70.5	7.2
Overall	**24**	**76.0**	**10.1**

Self-Aware			
		Score	
Group	Sample Size	Mean	Std. Dev.
UGR/REUVT	10	76.6	5.0
REUTUD	12	79.5	8.0
Dual BS	2	71.7	5.0
Overall	**24**	**77.6**	**7.0**

Willing to Take Risks			
		Score	
Group	Sample Size	Mean	Std. Dev.
UGR/REUVT	10	75.9	5.7
REUTUD	12	81.8 *	5.2
Dual BS	2	77.9	6.4
Overall	**24**	**79.0**	**6.2**

Open-Minded			
		Score	
Group	Sample Size	Mean	Std. Dev.
UGR/REUVT	10	74.8	8.4
REUTUD	12	78.3	19.2
Dual BS	2	70.0	1.3
Overall	**24**	**76.2**	**14.8**

Perceptive and Respectful of Diversity			
		Score	
Group	Sample Size	Mean	Std. Dev.
UGR/REUVT	10	71.9	8.9
REUTUD	12	73.5	16.7
Dual BS	2	65.0	20.0
Overall	**24**	**72.1**	**14.6**

n≥4 for t-test analysis
† = p<0.10, one-tail t-test
* = p<0.05, one-tail t-test
** = p<0.01, one-tail t-test

Internal Readiness Observations

As stated previously, the sample size for this study was very small, especially when considering the Dual BS group, which had only two participants. This disclaimer should be considered when reviewing the trends observed in this report.

The Undergraduate Researcher in Mechanical Engineering and Research Experiences for Undergraduates, Virginia Tech (UGR/REUVT) group served as a control in this study as the students did not participate in an education or experience abroad. The UGR/REUVT group's Overall Internal Readiness scores (74.6) were lower than the Research Experiences for Undergraduates, TU Darmstadt - Short Term Study Abroad to TUD (REUTUD) student group, which earned a mean score of 78.0. The VT-TUD Dual BSME degree group had such a low number of participants (two) that conclusions cannot be drawn with confidence.

The REUTUD group performed better than the UGR/REUVT group across every Internal Readiness component (Self-Aware, Willing to Take Risks, Open-Minded, and Perceptive and Respectful of Diversity). The education abroad experience had a measurable impact on attitudes, as was hypothesized in this study and has been observed routinely by Global Leadership Excellence. All groups scored in the *Developing Aptitude for Global Competence* range for Overall Internal Readiness.

Taken as a whole, the students performed best in the Willing to Take Risks component, with an overall mean score of 79.0. This high overall score was driven by the performance of the students who participated in an education abroad treatment. The REUTUD group's mean score of 81.8 was significantly different ($p<0.05$) from the control group's mean score of 75.9. In fact this component score (81.8) was the highest of any group or component measured by the GCAA®. Achieving the highest Internal Readiness category score in the Willing to Take Risks component is unusual, as it is commonly American's poorest performing Internal Readiness area. However the very nature of studying abroad is an overt demonstration of risk-taking in the transplantation of oneself to an unfamiliar environment. Global Leadership Excellence often observes that students who engage in education abroad experiences outperform the Willing to Take Risks scores of their peers who do not study abroad.

The lowest scoring component in the Internal Readiness category was Perceptive and Respectful of Diversity, where the overall mean score was 72.1. The REUTUD group scored somewhat higher than the UGR/REUVT group, with the former group earning a mean score of 73.5 and the former a mean score of 71.9; however, this difference was not significant.

With regards to variation, there was a spike in the REUTUD standard deviation in the Open-Minded and the Perceptive and Respectful of Diversity components. The mean scores appear to be driven down by an individual who earned very low scores in the two categories: 17.5 for Open-Minded; and 27.2 for Perceptive and Respectful of Diversity. If excluding that particular participant's responses, the difference between the control group and experimental group

would have been even greater for those factors. However, due to the extremely small sample sizes, the degree of human variation could not be overcome, hence no further significant differences were measured.

External Readiness Results

External Readiness			
		Score	
Group	Sample Size	Mean	Std. Dev.
UGR/REUVT	10	61.7	8.7
REUTUD	12	66.1	8.4
Dual BS	2	68.4	9.3
Overall	**24**	**64.4**	**9.0**

Globally Aware			
		Score	
Group	Sample Size	Mean	Std. Dev.
UGR/REUVT	10	55.0	11.0
REUTUD	12	65.9 *	10.0
Dual BS	2	58.2	9.8
Overall	**24**	**60.7**	**11.7**

Knowledgeable about World History			
		Score	
Group	Sample Size	Mean	Std. Dev.
UGR/REUVT	10	47.8	22.8
REUTUD	12	46.1	19.4
Dual BS	2	67.3	21.8
Overall	**24**	**48.6**	**21.8**

Interculturally Competent			
		Score	
Group	Sample Size	Mean	Std. Dev.
UGR/REUVT	10	66.4	14.5
REUTUD	12	73.2	11.5
Dual BS	2	75.0	15.0
Overall	**24**	**70.5**	**13.6**

Effective Across Cultures			
		Score	
Group	Sample Size	Mean	Std. Dev.
UGR/REUVT	10	79.5	10.4
REUTUD	12	78.6	10.4
Dual BS	2	76.1	10.2
Overall	**24**	**78.8**	**10.4**

n≥4 for t-test analysis

† = p<0.10, one-tail t-test

* = p<0.05, one-tail t-test

** = p<0.01, one-tail t-test

External Readiness Observations

As stated previously, the sample size for this study was very small, especially when considering the Dual BS group, which had only two participants. This disclaimer should be considered when reviewing the trends observed in this report.

Overall scores in the External Readiness category were significantly lower than Overall Internal Readiness scores. This effect was driven largely by poorer performance in the Knowledgeable about World History and the Globally Aware components. This phenomenon is often observed by Global Leadership Excellence. The Overall External Readiness mean score was 64.4 for all the participants in the study, with the UGR/REUVT control group scoring 61.7 and the REUTUD treatment group scoring 66.1. Both groups scored in the *Underdeveloped Aptitude for Global Competence* range.

The two Dual BS students earned a mean score of 68.4, which was in the *Developing Aptitude for Global Competence* range. Their highest mean score was driven by their stronger performance in the Knowledgeable about World History and the Interculturally Competent components. Due to the extremely small sample size, no further conclusions were noted with confidence about the performance of students in the Dual BS program.

The component in which students performed their worst was Knowledgeable about World History, where the overall mean score among all students was only 48.6. The UGR/REUVT control population earned a mean score of 47.8, while the REUTUD population's mean score was only marginally lower at only 46.1 (not significant). The REUTUD performance in the Knowledgeable about World History component was the lowest score in the External Readiness category, as well as the lowest score measured by the GCAA® in the entire study. This general phenomenon of poorest performance in the Knowledgeable about World History component is a trend that Global Leadership Excellence routinely observes. Also, there was a rather large degree of variability among the groups in the component due to a few outlier individuals in each group who performed especially poorly. As there is a penalty for wrong answer choices, these individuals likely incorrectly guessed on many questions which continually lowered their scores.

Overall, the students performed best in the Effective Across Cultures component where the participants' overall mean score was 78.8. In this instance, the UGR/REUVT student group earned the highest score (79.5), which was very closely followed by the REUTUD group's mean score (78.6 and not significantly different). It is not surprising that the groups performed comparably, as this particular component assesses collaboration and teamwork. Group projects were likely assigned to all students, regardless of their place of study, so such people skills were likely developed similarly despite the education locale. The engineering curriculum may itself enhance teamwork skills via laboratory partnering.

The most startling difference in performance was observed in the Globally Aware component, where the UGR/REUVT control group earned 55.0, yet the REUTUD group earned a 19.8% higher score of 65.9, which was significantly different ($p<0.05$). The REUTUD group's global knowledge, possibly contributing to their interest in self-selection of the study abroad program, and/or the impact of the program itself, greatly impacted their score.

An apparent difference was also noted in the Interculturally Competent component mean scores. The UGR/REUVT students earned a mean score of 66.4, while the REUTUD students earned a mean score of 73.2, which was 10.2% higher. It is not surprising that the students who studied abroad scored higher as they had more opportunity to learn the skill of adapting one's behaviors so as to assimilate into a different culture. However, due to the high degree of individual variation (SD = 14.5) in the small sample, the treatment difference was not calculated as statistically significant. As the p-value was relatively low (0.129), it is likely that a larger sample may assuage the human variation, allowing for a significant difference at the 90% confidence interval.

Trends Observed from Demographic Drivers

Internal Readiness

A number of demographic drivers contributed to Internal Readiness performance across all participants. Those capacities that affected attitudes included cross-cultural interaction time and cumulative time spent abroad. As used previously, the following key represents significant differences among samples containing four (4) or more respondents:

† = p<0.10, one-tail t-test
* = p<0.05, one-tail t-test
** = p<0.01, one-tail t-test

		Score	
Cross-Cultural Interaction Time per Day	**Sample Size**	**Mean**	**Std. Dev.**
None	4	69.8	4.9
Up to 1 hour	8	75.1	14.3
More than 1 hour and up to 2 hours	5	75.8	7.2
More than 2 hours and up to 4 hours	1	78.0	0.0
More than 4 hours	6	81.1 **	4.6
Overall	**24**	**76.0**	**10.1**

Cumulative Time Spent Abroad	Sample Size	Score	
		Mean	Std. Dev.
Never	2	72.1	6.1
Up to 6 months	10	76.1	5.6
More than 6 months and up to 1 year	4	82.2 †	6.5
More than 1 year and up to 3 years	4	80.6 †	4.0
More than 3 years and up to 5 years	1	84.5	0.0
More than 5 years	3	60.8	16.3
Overall	**24**	**76.0**	**10.1**

There is an apparent difference between Overall Internal Readiness of the juniors and the seniors, with the senior students outperforming their less educated peers. However, due to the very small sample size (three), the juniors were not included in the t-test. Ironically, the students who self-reported as being graduate students scored significantly lower than the baccalaureate students. It is possible that the Virginia Tech undergraduate curriculum provides more global competence development opportunity than the graduate students' past undergraduate programs and/or their current VT graduate programs.

Year of Education, if Currently a Student	Sample Size	Score	
		Mean	Std. Dev.
College Junior/3rd Year Post-Secondary Education	3	66.8	19.3
College Senior/4th or Final Year Post-Secondary Education	6	80.8	4.0
Graduate School	10	74.6 *	6.8
Overall	**24**	**76.0**	**10.1**

External Readiness

The capacity that contributed to External Readiness performance across all participants in a significant fashion was cumulative time spent abroad. This phenomenon was observed when comparing students with limited international travel experience (up to 6 months) with those who had spent a longer duration in another country:

		Score	
Cumulative Time Spent Abroad	**Sample Size**	**Mean**	**Std. Dev.**
Never	2	64.5	8.0
Up to 6 months	10	59.3	6.9
More than 6 months and up to 1 year	4	72.7 **	6.1
More than 1 year or and to 3 years	4	69.4 *	8.5
More than 3 years or and to 5 years	1	69.8	0.0
More than 5 years	3	62.1	8.1
Overall	**24**	**64.4**	**9.0**

Also, there is an apparent emerging trend with education experience, which should be followed in subsequent studies. However, as the sample size was very small among college juniors, it was not appropriate to conduct a t-test on the data:

		Score	
Year of Education, if Currently a Student	**Sample Size**	**Mean**	**Std. Dev.**
College Junior/3rd Year Post-Secondary Education	3	58.8	3.9
College Senior/4th or Final Year Post-Secondary Education	6	65.4	11.1
Graduate School	10	65.4	9.1
Overall	**24**	**64.4**	**9.0**

Conclusions and Recommendations

One can conclude that the education abroad experience had a positive impact on the global competence of the Virginia Tech Mechanical Engineering students who participated in this study. The students who had an education abroad component in their program performed better or similarly to students who did not study abroad. The impact of education abroad was seen most significantly in the Willing to Take Risks and Globally Aware components.

Demographic drivers to elevated performance against the Global Competence Model™ were observed with increased cross-cultural interaction time and increased time spent abroad. The GCAA® accounts for these factors, which would otherwise be overlooked in a traditional grouping of control versus treatment participants: the control students may have had experiences that contributed to their global competence outside the experimental design.

These observed phenomena support the hypothesis that further life experience, and/or study abroad increase the global competence of university students. In addition, the students who study abroad may have developed more interest in furthering their understanding of global issues than students who did not participate in education abroad programs. Based on these outcomes, one can conclude that supporting cross-cultural and education abroad programs and curricula are beneficial to Mechanical Engineering students, as such offerings significantly increased global readiness skills as measured by the GCAA®.

The greatest opportunities for improvement are in the Knowledgeable about World History and the Globally Aware components. These are areas that Virginia Tech Mechanical Engineering students can benefit from most readily in the classroom, which can be enhanced with continuous education via travel, reading, and international interactions.

GCAA® questions in the Knowledgeable about World History and Globally Aware areas focus around the entire world, and spotlight countries that play a strong role in the global economy and the world's population. Historically, American education has not focused on areas such as China, India, and the Middle East, however, to be globally competent, one needs to have general knowledge of the entire world. As history is the foundation of culture, and the understanding of global issues, trade, and geography, etc. increases one's global understanding, improving in these areas can further bolster one's performance in various cross-cultural situations, thus increasing one's global competence.

Growing one's Internal Readiness scores is less straightforward as it involves a shift in attitudes. It is not surprising that the REUTUD students' mean scores surpassed the UGR/REUVT students' scores, as the REUTUD students took risk in uprooting their lives to participate in an experience that was designed to open their minds to a new culture and environment. In so doing, they were likely exposed to diverse perspectives, which probably quite appropriately delays their judgment of others. Providing global on-campus academic and programming opportunities, as well as fostering an international student population, can mimic some aspects of education abroad to benefit domestic students, which can enhance their breadth of exposure.

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Appendix

Self-Aware: Having a balanced and honest view of one's own personality, and often an ability to interact with others frankly and confidently, recognizing how one fits into one's own society. *(Adapted from Encarta)*

Willing to Take Risks: Inclined to make mistakes, advocate unconventional or unpopular positions, or tackle extremely challenging problems without obvious solutions, such that one's personal growth, integrity, or accomplishments are enhanced. *(Adapted from North Central Regional Educational Library/Learning Point Associates)*

Open-Minded: Free from prejudice and receptive to new ideas (*Encarta).* Being critically receptive to alternative possibilities, being willing to think again despite having formed an opinion, and sincerely trying to avoid those conditions and offset those factors which constrain and distort our reflections *(William Hare, 2008)*

Perceptive and Respectful of Diversity: Showing insight, understanding, and thoughtfulness with regards to all of the ways in which people differ, including innate characteristics (such as age, race, gender, ethnicity, mental and physical abilities, and sexual orientation) and acquired characteristics (such as education, income, religion, work experience, language skills, geographic location, and family status). *(Adapted from U.S. Government, Office of Diversity and Inclusion, Human Resources)*

Globally Aware: Breadth of knowledge about nations and regions around the world, including their geographies, languages, religions, currencies, and cultures. Understanding the interconnectedness of countries and the shrinking of the world. *(William Hunter, 2007)*

Knowledgeable about World History: Familiarity or understanding, gained through experience or study, of the past events of a period in time or in the life or development of a people, an institution, or a place. *(Adapted from Encarta)*

Interculturally Competent: "The ability to communicate effectively and appropriately in intercultural situations based on one's intercultural knowledge, skills and attitudes." "The capacity to change one's knowledge, attitudes, and behaviors so as to be open and flexible to other cultures, has become a critical issue for individuals to survive in the globalized society of the 21st century." (*Darla Deardorff, 2004*)

Effective Across Cultures: The ability to function, collaborate, and work effectively within and across perceived or actual cultural barriers. (*William Hunter, 2007*)