Think Global, Act Global – for Engineering Problems and Solutions

Dr. Mohammad Moin Uddin, East Tennessee State University

Dr. Mohammad Moin Uddin is an assistant professor at the Department of Engineering Technology, Surveying and Digital Media at East Tennessee State University. His current research interest includes sustainable design and construction, system optimization, and instructional methods. Dr. Uddin has successfully incorporated innovative learning strategies in his courses which has significantly increased student engagement and satisfaction.

Dr. Keith V. Johnson, East Tennessee State University

Dr. Johnson is chair of the Department of Engineering Technology, Surveying and Digital Media at East Tennessee State University. He has been active with the American Society of Engineering Education for over 20 years. During that time, he have served in several capacities, including, but not limited to program chair, author, reviewer, committee member and is currently chair of the Engineering Technology Division. During his tenure at ETSU, he has authored several papers, taught numerous courses, and presented at professional meetings.

Think Global, Act Global – for Engineering Problems and Solutions

Abstract

The discipline of engineering and technology is no longer an isolated field of human activities and the future role of engineering demands that social, ethical and cultural aspects should be added to the technical dimension of engineering education. In this age of globalization, engineers should have deeper concepts, wider views, more skills, and integrated tools to meet the challenges of the expanding spheres of knowledge and the challenges of globalization. Effective and transformative global learning offers students meaningful opportunities to analyze and explore complex global challenges, collaborate respectfully with diverse others, apply learning to take responsible action in contemporary global contexts, and evaluate the goals, methods, and consequences of that action. Global learning enhance students' sense of identity, community, ethics, and perspective-taking. Global learning is based on the principle that the world is a collection of interdependent yet inequitable systems and that engineering education has a vital role in expanding knowledge of human and natural systems, privilege and stratification, and sustainability and smart development to foster individuals' ability to advance technology application, equity and justice at home and abroad.

ENTC 4600: Technical Practicum is a senior level required capstone design course offered by the department of engineering technology, surveying and digital media. This course is offered every semester and requires the student to synthesize and apply subject matter studies in previous required courses and apply them to a realistic problem solving effort. In the Fall 2013, the ENTC 4600 course's learning outcomes were modified to infuse global perspectives of engineering problems and solutions. In that semester, students explored international markets mainly developing countries, identified an engineering and technology related problem with the collaboration of a focus group (consists of international students), and then designed and developed a solution to mitigate the problem. It was anticipated that the students would learn about international business environment, cross cultural elements of engineering problems, and sustainable solutions. Students learning outcomes were evaluated using pre and post survey, focus group's evaluation, and peer evaluation. A sensitivity analysis was also conducted to justify effectiveness of new learning outcomes. All students agreed that the course project increased their knowledge and skills to solve engineering problems in global settings. About 92% students responded that the project increased their interest about different cultures and multi-perspective analysis, and 72% students, up 52% from pre-survey, said that the project was helpful understanding engineering and technology related practices, standards, specifications, safety outside USA. This paper presents effectiveness of proposed course modifications and engaging international students with American students as a method to teach global skills. The paper summarizes course preparation, organization, challenges, and opportunities to enhance global education experiences for engineering technology students which can be transmitted in other areas.

I. Introduction

The world economy is globalizing at an accelerating pace. Ambitious growth-minded companies are racing to build stronger competitive positions in the markets of more and more countries. Globalization has transformed the way businesses operate and has changed the character of the engineering profession. As a result more companies are now looking for engineers and technologists with diverse skill sets capable of providing engineering solutions not only in domestic markets but beyond domestic boundaries[1,2]. Increasingly, successful entry into the engineering profession now requires significant intercultural and social skills in order to join efficient and productive collaborations with diverse engineering partners. Those partners may be encountered virtually at a distance, in person at an international site, next door in the office of a multinational corporation or by working with international suppliers, providing services to international product markets, and/or developing products that have an appeal on the international market1. More and more projects are now distributed across global sites and effective collaboration requires professionals who can work productively with colleagues who are very different from themselves.

Academic, industry and government institutions have recognized the need of global competencies for engineering students. Grandin (2009) discussed the value added through the experience of engineering work and study abroad, as well as on the lessons learned over the seventeen year history of the University of Rhode Island program[3]. The paper emphasized that to be competitive in global workplace engineers must be educated as global citizens, trained to work in global teams, and prepared to develop and manufacture for a global market. Without these skills, they will fail and their work will be handed off to peers from other parts of the world where such global preparation is already valued and broadly practiced. Downey et al. (2006), Parkinson (2007), and Lohmann et al.(2006) developed measures of global engineering competence[4,5,6]. In Parkinson et al. (2007), the authors proposed 13 attributes of global competence, and present the results of a survey which gathered feedback from people in academia and industry on the relative importance of these 13 attributes. Recognizing the need to equip their graduates with the right skills to stay globally competitive, as a result, a number of universities have developed effective internationalization strategies (Berka, 2009)[7]. A series of studies focused on best practices for both scholars and practitioners of global engineering practices [Jesiek et.al (2010), Chang et.al. (2009), and Groll and Hirleman (2007)][8,9,10]. Kathrin Köster, in her textbook, *International Project Management*, pointed out fundamental differences between a “standard” project and an “international project and notes the need to more fully integrate cultural dimensions and a multidisciplinary approach to project management by using case studies[11]. The U.S. National Academy of Engineering published two reports - both stress the impact of globalization on the practice of engineering and the need for U.S. engineers to focus on innovation and creative aspects of the profession to be globally competitive[12,13].

Positive aspects of global competence have been noted. For example, Montgomery (2009) attributed improved student views in cross-cultural group work to internationalization efforts over the past decade[14]. Dolby (2004) discusses the impact of study abroad on national identity[15]. Grandin (2004) elaborated the benefits of exposure to another culture, learning another language, developing an appreciation for other cultural perspectives, learning to be mobile, viewing and experiencing difference in many aspects of life and society[16]. In his case study report, most of the project participants have pointed out that the year spent abroad helped them develop ability to accept challenges and solve problems independently which may not be experienced in the U.S.

Various approaches are taken by universities to internationalize engineering education which include various types of study abroad, research abroad or internship programs or a combination of these, e.g. the GEARE at Purdue, the MISTI at MIT, or the IEP at URI. Parkinson (2007) has compiled a comprehensive overview of these different attempts to globalize engineering education via exchange programs, dual degree programs, international project work and internships[5]. The above mentioned programs are very effective to develop global competence for engineering technology students. However, several constraints such as desirability, affordability, language, safety etc. pose as major barriers for most students to participate in such programs.

International student groups bring significant cultural diversity on a university campus. In 2012/13, an estimated 819,644 international students studied in US with 19% (2nd highest) enrolled in various engineering and technology programs[17]. International students and associations promote awareness of cultural diversity and global understanding within the university and the broader community. Engaging local students with these diverse groups of international students through activities, group projects, and discussions can be an effective way of exposing students to learn cultural diversity, practices, ethics, and thereby preparing engineers for the global workforce.

This paper focuses on educating engineers/engineering technology students as a global citizen and problem solver by engaging them with the international student groups. The research hypothesis is that international student groups and communities on the university campus can effectively help engineering technology students learn global skills through active and peer learning, and may serve as an alternative to study abroad. The course project for the capstone design course was used to test the hypothesis. The paper is divided into five sections. The first section describes the planning for the course modifications and the second section describes added learning outcomes. The third section explains evaluation and assessments. Major outcomes and lesson learned are included in the conclusion section. The paper is concluded with a limitation and recommendation section.

II. The Course Design

ENTC 4600: Technical Practicum is a senior level required capstone design course offered by the department of engineering technology, surveying and digital media. This course is offered every semester with enrollment of about 40 students each year. The course requires the student to synthesize and apply subject matter studies in previous required courses and apply them to a realistic problem solving effort. For example, in manufacturing, students will draw upon their knowledge of product design and manufacturing methods to solve a complex problem, commonly designing and developing a manufactured product. In a typical project students identify a product or service need in the community or in industry and then design and develop a prototype from scratch.

The Project

In the Fall 2013 semester the ENTC 4600 course’s learning outcomes are modified to infuse global perspectives of engineering problems and sustainable solutions. Currently there are five course outcomes focusing on enhancing students' creativity, technical competences, sustainability integration, project management, teamwork, and leadership skills. The modified course did not exclude any of these outcomes but broaden the scope of the course by preparing students with global competencies.

In that semester, students looked at international markets mainly developing countries, identified an engineering and technology related problem (i.e. a product and service needs) with the collaboration of an international student group at East Tennessee State University (ETSU), and then devised a solution (i.e. designed and developed a product or service) to meet the customers needs. A total of 3 groups were formed and undertook three engineering problem solving projects focusing on Asian nation of China and African nation of Nigeria. There are several phases for the projects:

Phase I: During the summer of 2013, instructors (authors) made necessary changes in the course curriculum to add the international dimensions through research and development. Instructors identified textbook, case studies, journal articles, web contents, audio-visual contents, etc. and developed a modified course curriculum. Instructor identified locally based international resources: students and community personnel and recruit a group of international students from China and Nigeria to collaborate with students during the semester. The internationals students were divided into two groups. The first international student group took part during idea generation and collaborated with the teams throughout the semester. The second group took part as a focus group to provide unbiased evaluation to the solutions.

Phase II: Two weeks before the semester starts students were introduced the new internationalization infused course curriculum. Students were encouraged to research global markets and generate ideas of creative products and services for their country of interest.

Phase III: Class preparation - throughout the semester, instructor taught concepts of engineering problem solving from global perspective using texts, reports, journal articles, case studies, audio, video, etc. Four guest speakers were invited who talked about design and development, international business environment, business plan, manufacturing, testing, and specifications appropriate global communities throughout the semester. At the end of first week of class, students were formally introduced to the international student group and collaboratively they identify potential products and services. Students then put their ideas into design and develop a prototype which is culturally, socially and environmentally justified.

Phase IV: Students presented their product and services, and the second international student group evaluated them.

Phase V: Students prepared a report with detail design, manufacturing processes and specifications.

III. Added Learning Outcomes

The course has five learning outcomes which are aligned along ABET student outcomes a to h. An additional learning outcome which focuses on global perspectives of engineering problems and solution was included. The proposed learning outcome has several components. These are:

International Business Environment

The current learning outcome for the course is somewhat “Think Local, Act Local”. Students identify an engineering problem in the community or in industry and then develop a product or service to fit local customers, regulations, and market requirements. One of the anticipated learning outcomes of the proposed curriculum modification was to broaden the course objective to “Think Global, Act Global”. Students are expected to learn about global business dynamics, economic integration, supply demand, manufacturing, supply chain, logistics, etc. which enhance students understanding about multinational businesses and global engineering problems, and needs for solutions.

Cross Cultural Elements of Engineering Problems and Solutions

Differing population sizes, income levels, demographic, political and cultural factors give rise to considerable differences in market size. Buyer tastes for a particular product or service sometimes differ substantially from country to country. Sometimes, product designs suitable in one country are inappropriate in another because of differing local standards – for example, in USA electrical devices run on 110 volt systems, but in south East Asian countries the standard is a 240 volt, necessitating the use of different electrical design and components. Students have to decide whether and how much to customize their products or services to match the tastes and preferences of local buyers of a geographic location. Students are expected to learn about all these cultural, political and economic forces that drive and are driven by technology and how to factor in those in product design and development.

Sustainable Development

Sustainability is already a learning outcome for this course. However, its focus is limited. The concept of sustainability is elaborated with the focus of triple bottom line. Students learned about critical global environmental issues and make sure that sustainable solutions are considered and implemented in their products or service development.

Socially Complex Collaboration

Students worked with an international group of students throughout the project. This is a unique collaboration experience for local students. Students are expected to learn tacit and socially complex knowledge from international students, cultural aspects, social norms, standards, local practices which could be unreachable without such interactions.

IV. Assessment of Learning Outcomes

The international students were introduced with the local American students in the first week of the class and collaboration continued throughout the semester. Four guest lecturers with expertise in design and development, global business, and manufacturing spoke in the class at different stage of the project development. Instructor stimulated the students’ learning experience with small activities, lectures, and discussion. Modifications in the current course curriculum and anticipated learning outcomes are evaluated in several ways:

Students' Performance

The anticipated outcomes of the proposed modifications are assessed through evaluation of a series of student presentations and report writings. Students prepared a total of 5 presentations, four item based reports and a final report – each chronologically depicts search for an engineering problem in their country of interest, understanding of various dimensions of international arena, conceptual design focusing on local preferences, a business plan, prototype design, manufacturing process and the final product development. A pre and a post survey were conducted to assess effectiveness of learning outcomes.

The pre survey assessed students' initial understanding of global citizenship, their knowledge and preparation, and willingness to engage in local, global, and intercultural problem solving. Students were asked Yes/No questions and/or rate statements based on 5 point Likert scale: 1- strongly disagree, 2 – disagree, 3 – neither agree nor disagree, 4 – agree and 5- strongly agree. Table 1 shows students' responses and rating percentage in key items of the pre survey. As shown in Table 1, most students had no international experience (82%) and unfamiliar with engineering and technology related standards and specifications outside USA (80%). However, about 82% students responded that they understand interplay among regional cultures, socio-economical and political influences in engineering problems and development of solutions.

Table 1: Pre Survey Responses

Question or Statements	**Yes**	**No**	**Likert Scale Rating**				
			1	2	3	4	5
Do you have an international education experience such as study abroad?	18%	82%					
I can communicate effectively at least one foreign language	18%	82%					
I am familiar with SI Units for problem solving	100%						
I am familiar with engineering and technology related standards and specifications outside USA	20%	80%					
U.N. Millennium Development Goals, which USA supports, also reflect the need for a Global Education Perspective to achieve success					10%	27%	63%
I see the relevance of international issues such as cultural, socio-economical, political etc. in engineering problems and solutions			9%	9%		36%	46%
I believe that in future, I will need to work in environment where the communication with individuals with different background, knowledge and/or language will be necessary				18%		18%	64%
I value diversity and multi-perspective analysis of an issue			9%		27%		64%
I believe understanding sustainability is essential to join the international discourse and work cooperatively in the closely interconnected world of the new millennium			9%	10%		36%	45%
I am preparing myself to be a global citizen			10%	10%	20%	40%	20%

Significant number of students value diversity and believe that in future they will work in diverse environments. More than 80% students emphasize the importance of sustainable solutions and 60% students responded that they are preparing themselves to be global citizen.

A post-survey was conducted to assess students' global learning experience and effectiveness of course program. A similar format as in pre survey was used in developing the survey. Table 2 summarizes students' responses and rating percentage in key items of the post survey. As shown in Table 2, engaging international students in identifying engineering and technology related problems and solutions was a huge success. All students agreed that the course project increased their knowledge and skills to solve engineering problems in global settings. The students utilized their knowledge of mathematics, science, and tools and techniques learned in other technology courses and significantly challenged their critical thinking skills. About 92% students responded that the project increased their interest about different cultures and multi-perspective analysis, and 72% students, up 52% from pre-survey, said that the project was helpful understanding engineering and technology related practices, standards, specifications, safety outside USA. Since sustainability was a project requirement, at least 65% reported that the course materials and the project expanded students' knowledge about sustainability by balancing environmental protection, social responsibility and economic growth.

Table 2: Post Survey Responses

Question or Statements	**Yes**	**No**	**Likert Scale Rating**				
			1	2	3	4	5
The project increased my knowledge and skills to solve engineering problems in global settings	100%						
Did the project challenge you to use critical thinking skills?	100%						
The project prepares me to apply the knowledge of mathematics, science and engineering to design systems, components or processes	100%						
The project prepares me to conduct tests and measurements, and interpret experimental results	92%	8%					
Was this experience helpful understanding engineering and technology related practices, standards, specifications, safety outside USA?	72%	28%					
Does this project increase you interest about different cultures, practices, diversity, multi-perspective analysis?	92%	8%					
The project enhances my teamwork and leadership skills						10%	90%
The project improves time, cost, quality and communication management skills						12%	88%
The course materials and the project expand my knowledge about sustainability by balancing environmental protection, social responsibility and economic growth at home and abroad				14%	21%	57%	8%

International Student Group and Peer Group Evaluation

The first international student group routinely collaborated with the local students throughout the semester. A second international student group was brought for sensitivity analysis when projects were completed. This second group was not exposed to the projects before and they served as customer body and evaluated the product or service developed. Local students also act as peer for each other projects. A final survey was prepared for international students and peer group to measure effectiveness of the solution developed. The evaluation was conducted based on the four fundamental project requirements that were introduced at the beginning of the semester. These four project requirements were:

PR1: The solution (the product) meets the requirements of the clients' needs in the country of interest

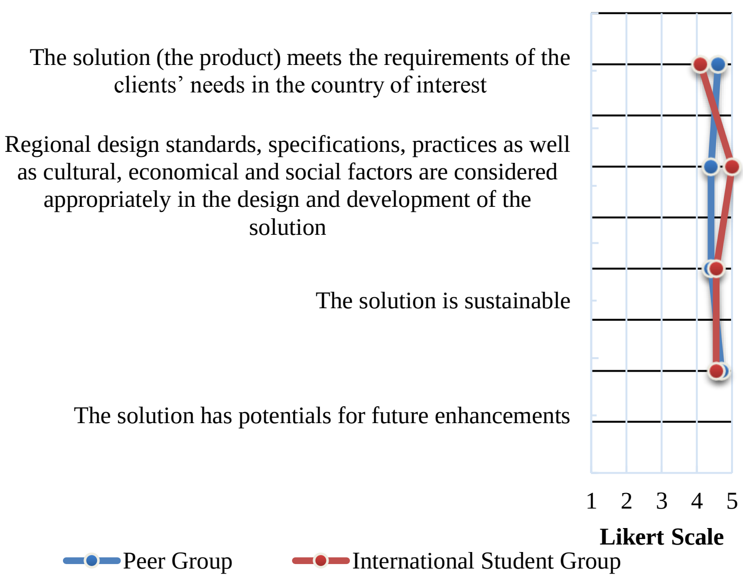
PR2: Regional design standards, specifications, practices as well as cultural, economical and social factors are considered appropriately in the design and development of the solution

PR3: The solution is sustainable

PR4: The solution has potentials for future enhancements

Evaluation was done on 5 point Likert scale as mentioned earlier. Likert scale data are ordinal type data, and the adequacy of treating ordinal data as interval data continues to be controversial in survey analyses in a variety of applied fields.[18,19,20] Nonparametric tests, even though less powerful, are recommended by experts as a result. Kruskall-Wallis test, which is a non parametric test based on ranks was used to evaluate students' performance in four project requirements and compare international students vs peer evaluation. As shown in Figures 1, 2, and 3, all three projects that students completed, both international students and peer group scored them 4 or higher in all four PR categories. This means that students met project requirements overwhelmingly. The p-values for Kruskal-Wallis test for all three projects show not significant except PR3 and PR4 for project 1. This implies that both international student group and peer group agree in their evaluations.

Kruskal-Wallis Test

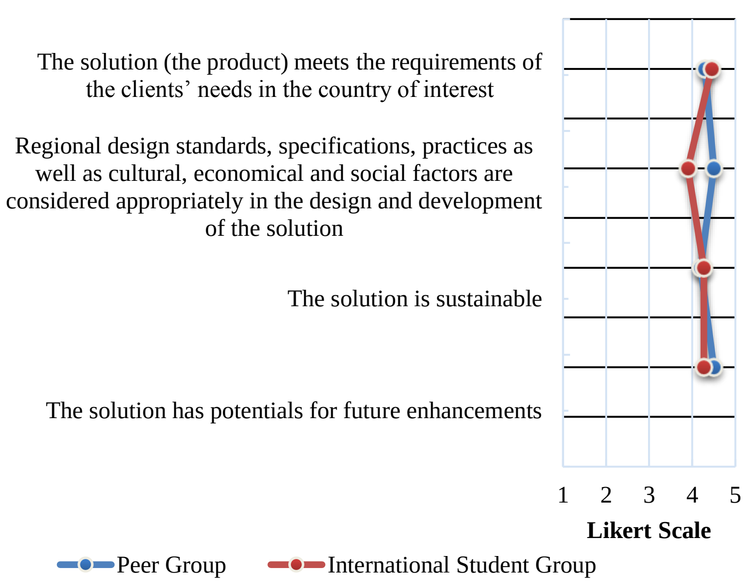


	Project Req.	*p* - *value*	Comment
International student group vs. Peer group	*PR1*	0.477	Not Significant
	PR2	0.690	Not Significant
	PR3	0.023	Significant
	PR4	0.047	Significant

Alpha = 0.05

Figure 1. Student Performance Evaluation for Project 1.

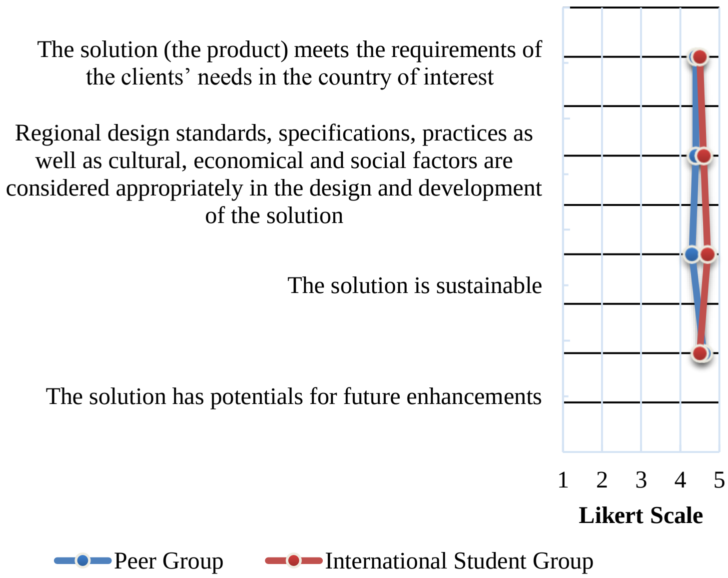
Kruskal-Wallis Test



	Project Req.	*p* - *value*	Comment
International student group vs. Peer group	*PR1*	0.369	Not Significant
	PR2	0.780	Not Significant
	PR3	0.063	Not Significant
	PR4	0.632	Not Significant

Alpha = 0.05

Figure 2. Student Performance Evaluation for Project 2.



Kruskal-Wallis Test

	Project Req.	*p - value*	Comment
International student group vs. Peer group	*PR1*	0.861	Not Significant
	PR2	0.081	Not Significant
	PR3	0.434	Not Significant
	PR4	0.661	Not Significant

Alpha = 0.05

Figure 3: Student Performance Evaluation for Project 3.

V. Conclusions

ABET requires that engineering technology programs must demonstrate that their students attain the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context. Therefore, engineering technology students need to have a new set of skills, referred to as global competence. Global competency is essential for engineers and technologists from any country which now competes in an international market for engineering know-how. Engineering technology students who have international study experience are more likely to be hired and prepared for the global market place. However, very few American engineering students have any international experience. According to Open Doors report only 9.4% of all US undergraduates study abroad during their degree programs[17]. A vast majority of students have little to no exposure to investigate engineering problems and solutions under global lens. This paper presents an alternative yet effective method of teaching students global competency. This method involves systematically engaging students with the international student groups and communities though group activities, team project, discussion and other activities. Based on the data presented, the proposed course modifications greatly enhance students' understanding about global engineering problems, how to develop socially justified sustainable solutions and be a global citizen. The course project significantly challenge students' critical thinking skills and help them understanding engineering and technology related practices, standards, specifications, safety outside USA. This will ultimately increase students' employability and advance their career in global economy.

VI. Limitation of the Study and Recommendations

The major limitation of the paper is that inferences are made based on limited data. More data collection and focused analysis are necessary to further validate the premise. Another limitation of the study is that there was not a control group in the study to evaluate if an all American group would perform equally as well as the group with international students. One key challenge was coordination between American and international students and keeping both groups focused. These authors recommend extensive planning, focused lecturing and briefing on global skills, developing extensive guidelines for collaboration, and stipends for international students for better results.

Reference

1. Grandin, J. M. and Hirleman, E. D. (2009). “Educating Engineers as Global Citizens: A Call for Action/ A Report of the National Summit Meeting on the Globalization of Engineering Education.” *Online Journal for Global Engineering Education*, 4(1), 1-27.

2. Klahr, S. C. and Ratti, U. (2000). “Increasing Engineering Student Participation in Study Abroad: A Study of U.S. and European Programs.” *Journal of Studies in International Education*, 4(1), 79-102

3. Grandin, J. M. (2006). “Preparing Engineers for the Global Workplace: The University of Rhode Island.” *Online Journal for Global Engineering Education*, 1(1), 1-8.

4. Downey, G.L., Lucena, J.C., Moskal, B.M., Bigley, T., Hays, C., Jesiek, B., Kelly, L., Lehr, J., Miller, J., Nichols-Belo, A., Ruff, S., and Parkhurst, R. (2006). “The globally competent engineer: working effectively with people who define problems differently.” *Journal of Engineering Education*, 95(2) 107-122

5. Parkinson, A. (2007). “Engineering Study Abroad Programs: Formats, Challenges, Best Practices,” *Online Journal for Global Engineering Education*, 2(2), 1-15

6. Lohmann, J. R., Rollins, H. A. and Hoey, J. (2006). “Defining, developing and assessing global competence in engineers.” *European Journal of Engineering Education*. 31(1), 119-131

7. Berka, Sigrid. (2009). “Institutional Strategies: Seven Cases.” *Online Journal for Global Engineering Education*, special volume on Educating Engineers as Global Citizens: A Call for Action/ A Report of the National Summit Meeting on the globalization of Engineering Education, edited by John M. Grandin and E. Dan Hirleman, 4(1) p22.

8. Jesiek, B. K., Borrego, M., Beddoes, K. (2010). “Advancing Global Capacity for Engineering Education Research (AGCEER): Relating Research to Practice, Policy, and Industry.” *Journal of Engineering Education*. 99(2), 107-119

9. Chang, Y., Atkinson, D., Hirleman, D. E. (2009). “International Research and Engineering Education: Impact and Best Practices.” *Online Journal for Global Engineering Education,* 4(2), 1-8

10. Groll, E. A and Hirleman, E. D., (2007). Undergraduate GEARE Program: Purdue University’s School of ME Contribution to Educating Globally Sensitive and Competent Engineers**.** http://globalhub.org/resources/194/download/2007aseegceeistanbulmanuscriptgroll.pdf. Accessed on Dec 12, 2013.

11. Köster, K (2010). *International Project Management*, Sage Publications, London.

12. National Academies of Engineering, “The Engineer of 2020: Vision of Engineering in the New Century,” National Academies Press, Washington, DC, 2004.

13. National Academies of Engineering, “The Engineer of 2020: Adapting Engineering

Education to the New Century," National Academies Press, Washington, DC, 2005.

14. Montgomery, C. (2009) "A Decade of Internationalisation: Has It Influenced Students' Views of Cross-Cultural Group Work at University?" *Journal of Studies in International Education*, 13(2), 256-270
15. Dolby, N. (2004) "Encountering an American Self: Study Abroad and National Identity" *Comparative Education Review*, 48(2),150-173
16. Grandin, J. M. (2004) "Globalization: A Look at the Positive Side", *Globalization and Language*, ed. Bernd Huppauf, NYU, USA.
17. Institute of International Education (2011) Open Doors 2013 Fast Facts. http://www.iie.org/Research-and-Publications/Open-Doors/Data Accessed on Dec 15, 2013
18. Gideon, V. (1977) "The Level of Measurement and 'Permissible' Statistical Analysis in Social Research," *Pacific Sociological Review*, 20(1), 61-72.
19. Jakobsson, U. (2004) "Statistical Presentation and Analysis of Ordinal Data in Nursing Research," *Scandinavian Journal of Caring Sciences*, 18, 437- 440.
20. Clasen, D. L. and Dormody, T. J. (1994) "Analyzing Data Measured by Individual Likert-Type Items," *Journal of Agricultural Education*, 35(4), 31-35