Student Outcomes Of Participating in an International Research Experience

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Abstract

Current engineering literature calls for engineers to develop global competencies through international experiences. Studies have examined whether or not students develop global competencies, but there are fewer studies that look at how those competencies translate to the research environment. The International Research Experience for Students (IRES) at Virginia Polytechnic Institute and State University (Virginia Tech) allows College of Engineering graduate students and undergraduates the opportunity to participate in a guided research experience over a range of engineering fields at the University of Nottingham over a summer. The students spend three weeks prepping at Virginia Tech and then immediately travel to the UK for seven weeks of full-time research. In this paper, we provide a detailed explanation of the IRES program and use a mixed methods study to explore whether the comprehensive international experience had any impact on the participants' development of global competencies and any impact on the participants' international research skills. Results indicate that the IRES program structure facilitates increased cultural knowledge and understanding of the challenges and benefits associated with international research. Two other significant findings were that after participating in the program, students indicate cultural knowledge is necessary in completing an international assignment and that participation also influenced students' perceptions of what skills are needed to participate in international research.

Introduction

Nationally, higher education institutions are considering how to develop engineers who possess content knowledge but also understand how culture can play a role in the success of solutions and designs. Engineers and scientists with an appreciation for, and possessing, global competencies as well as an understanding of how collaborating on research with international partners can advance problem-based solutions is increasingly important. This paper describes the approach used at Virginia Tech to address these learning goals through the International Research Experience for Students (IRES) program. In addition to the detailed program description, we use data collected from IRES program evaluation efforts to examine whether the comprehensive international experience had any impact on participants' development of global competencies and confidence in ability to conduct international research.

Program Overview

IRES is a collaborative program between Virginia Tech, College of Engineering and the University of Nottingham, Faculty of Engineering, now entering its fourth year. The program facilitates the exchange of students, faculty, technology and ideas pursuant to researching future electronic transport systems and alternative energy systems. This strong institutional partnership provides students with the opportunity to conduct this international research while acquiring globally minded engineering practices. The National Science Foundation grant (#1261162**)** supports up to (10) students from Virginia Tech in conducting paid summer research related to their academic and professional interests under the mentorship of faculty members at the University of Nottingham and in cooperation with Virginia Tech faculty. The research portion of the program is comprised of (10) weeks divided into (3) weeks of preparatory research at

Virginia Tech followed by (7) weeks of intensive research abroad at the University of Nottingham. Faculty introduce students to foundational research methodologies and/or advanced techniques depending on their technical experience. Students are challenged to conduct their research critically as they find themselves immersed in a new cultural environment.

All Virginia Tech, College of Engineering students (with United States Citizenship or permanent residency) are welcome to apply to the IRES Program. Both graduate and undergraduate students (recommended to be above the sophomore level) are invited to apply during the fall semester. Students designate their preference out of one of five internationally recognized research groups embodied by the Virginia University of Nottingham's research centers - The Power Electronics, Machines and Control Research Group (PEMC), The Rolls-Royce University Technology Center (UTC), The Human Factors Research Group (HFRG), the Geoenergy Research Centre (GeRC) or Mechanical, Materials and Manufacturing Engineering/ Polymer Engineering (Dept). Applications are reviewed by the Virginia Tech Global Engineering, Engagement and Research Office (GEER) and faculty associated with the applicants' research goals. Finalists are invited to interviews co-conducted by the Virginia Tech GEER Office and faculty at Virginia Tech and the University of Nottingham. Having both groups (i.e., the GEER Office and faculty) participate in the interviews provide an objective environment in which to judge the potential readiness and success in carrying out international research. Interviewers gauge the level of interest that students demonstrate in connecting the potential impact of their research to societal problems and arrange mutually beneficial research partnerships between students and faculty.

Once selected, students are co-advised by faculty from Virginia Tech and the University of Nottingham on projects of joint institutional interest. Students are required to attend several pre-departure workshops which include (3) Orientations during the Spring Semester and a (3) week Research Planning Seminar at the beginning of Summer I/Summer Session. These workshops prepare students for living and working in a new cultural environment and drafting their research project timelines.

The three orientation workshops in February, March, and April of the spring semester introduces the structural aspects of the program and the innate challenges of the summer experience including culture shock, research troubleshooting and international travel. Students also complete a Faculty-Student Research Agreement with their advisors beginning in March to design a mutually agreed upon research plan. During these workshops, students also complete university paperwork and secure flights, health insurance and housing under the guidance of the Global Engineering, Engagement and Research Office.

During Summer I session, students attend a mandatory and facilitated (3) three-week Research Planning Seminar at Virginia Tech prior to their departure for the University of Nottingham. Students develop a problem statement and scope for their anticipated research; identify relevant literature; plan research goals and deliverables; and develop a project timeline that includes required facilities and resources, guiding methodologies, test plans, and data analysis. At the end of the three weeks, the students submit and present a research proposal to both the Virginia Tech and UoN research faculty.

Faculty participation is consistent throughout the IRES program. Their involvement begins with student recruitment and continues through application review, advising, research execution and conference preparation. Faculty from each school co-advise the students on their research proposals and assist in mapping out a focused timeline for their seven weeks abroad. Only committed faculty retain placement with the IRES program as their interaction with students is paramount to their development as global scholars and professionals. Faculty are encouraged to integrate cultural awareness activities into their students' research but much of this happens organically as students collaborate with their respective international teams. The co-advising of students often continues after completion of the 10-week research experience. In fact, 14 graduate students have been jointly advised since 2013.

An orientation and welcome session are held at the University of Nottingham upon student arrival. Students then spend seven weeks at the University of Nottingham engaged in concentrated research activities, often working collaboratively as part of a large team including faculty, Ph.D. students, and postdoctoral research fellows who also act as mentors. Program administrators encourage students to travel on the weekends in order to learn about U.K. history, industry and culture. The Virginia Tech Global Engineering, Engagement and Research Office is available to assist students with any travel queries.

Upon returning to the Virginia Tech campus, each IRES student must present their results at a student research symposium or professional conference. Undergraduate students can select from a list of opportunities organized under the Virginia Tech Office of Undergraduate Research. Graduate students may participate either in the on-campus GSA (Graduate Student Association) Research Symposium or professional conference of their choosing or at the recommendation of their faculty advisors.

Evaluation activities are linked to the program administration and student schedule. Students are administered an online pre-survey during the first session of the summer pre-departure workshop. They also receive an online post-survey during the final week of their summer research experience in the UK. The Global Engineering, Engagement and Research Office hosts a debrief session with the students a few weeks after their return to the U.S. Student feedback aids program administrators/coordinators in improving the International Research Experience for students for future Hokies.

Conceptual Framework

Multiple studies have examined the benefits of international research programs. For non-major specific groups of students, studies have found that participation in an international research experience coupled with a pre-trip orientation leads to increased global awareness, enhanced study abroad experiences, or a more immersive experience during their research. Streitwieser and Leephaibul (2007) completed pre-and post-surveys with Northwestern University students who participated in the Study Abroad Research Program. This program follows the same format as Virginia Tech's IRES program in that students attend trainings at their domestic university before going abroad to complete supervised research. They found that students' study abroad experience is enhanced by having the opportunity to discuss foreign cultures with other students and faculty members before departing, and research often creates a more immersive experience

in local culture than just taking classes. Similarly, Ragusa, Matherly, and Phillips (2014) compared undergraduate students in an international research abroad program to those participating in a domestic research program. Both programs provided three weeks of orientation before eight weeks of research and students were given the Engineering Global Preparedness Index (EGPI) at the beginning and end of the program. The four scales of the EGPI are *Global Engineering Ethics and Humanitarian Values; Global Engineering Efficacy; Engineering Global-centrism;* and *Global Engineering Community Connectedness.* At the post-test, the international research students scored higher than domestic students on three of the four scales (all except *Engineering Global-centrism).* Similarly, the international research students improved three of their four scales from pre-test to post-test (*Global Engineering Ethics and Humanitarian Values; Global Engineering Efficacy;* and *Global Engineering Community Connectedness);* the domestic students decreased on all four scales. Fleming, Burrell, Patterson, Fredericks, and Chouikha (2014) examined Howard University undergraduate students who participated in a research study abroad. All participants increased skills in Communication Issues (language, technology challenges); Coordination & Time Restraints (scheduling meetings, getting equipment); Research Engagement (excited about projects, hands-on experience); and Positive Impact of Experiences (developed relationships, global awareness.)

In terms of effectiveness of orientation programs for study abroad research participant, Jesiek, Haller, and Thompson (2014) separated participants in a summer research abroad program into three orientation groups; one group had a domestic-soil orientation, one group had a foreign-soil orientation, and the third group had an entirely online orientation. The foreign-soil and domestic-soil orientation participants, both graduate and undergraduate, had significant increases in perceptions of readiness for their trip abroad. Further, the foreign-soil group had the largest gains in their perceived readiness to sojourn, while the online group had no significant change.

Given the aims and goals of the IRES program we were interested to understand whether the program activities were achieving the goals of the program. We were also interested in exploring program outcomes using both qualitative and quantitative methods given that most of the previous studies relied solely on quantitative approaches. Specifically, we were interested in understanding whether students developed global competencies, confidence in research skills, and an understanding of the benefits and complexities of international research.

Methodology

To answer the research questions guiding our study we used the pre/post responses from three cohorts of students that participated in the IRES program in the summers of 2014 (n=5), 2015 (n=13), and 2016 (n= 5). The data sets from each cohort were combined to create one pre-test and one post test data set

The quantitative data were collected from the Cultural Intelligence Scale (CQS) developed by Van Dyne and Ang (2012). This 20 item instrument measures four different domains associated with a person's capability to operate in culturally diverse situations. Domains include Cultural Strategy, Cultural Knowledge, Cultural Motivation, and Cultural Behavior. Survey questions also included a series of questions that asked students about their research self-efficacy and to rate themselves on their research ability. Questions included ability to manage a team, identify

research problems, and communicate their findings. Qualitative data were collected from the Global Engineering Competency Activity (Jesiek, 2011) an open-ended question that asked respondents to consider themselves as a working engineer in an international location. The respondent in this imagined role was asked to consider how they needed to be prepared to enter into this international work situation and list five capabilities and/or things they would need to know. Given the low number of participants we were not able to run detailed statistical analyses.

Descriptive statistics were used to compare the pre/post responses of the students. Open-ended responses were analyzed using an *a priori* coding scheme based on the constructs we were most interested in learning about including global competencies and international research skills. First the pre-test responses were analyzed to see what themes emerged and then the post responses were analyzed to see what themes emerged. Themes were then classified into a set of codes and the codes from the pre-test data set were compared to the post to see if there were any changes in student responses over the course of the summer.

Results

The first question of the pre- and post-test for IRES participants asked them to agree or disagree with items about their beliefs, preferences, and attitudes toward people with different cultural backgrounds using a 7-point Likert scale. For eighteen of the twenty items, students' agreement in having positive beliefs, preferences and attitudes increased. For one item (*I alter my facial expressions when a cross-cultural interaction requires it*), the score remained exactly the same from pre-test to post-test. The only item on the test for which students' post-test agreement decreased was *I am sure I can deal with the stresses of adjusting to a culture that is new to me*, which has been bolded in Table 1. All three-year averages can be found in Table 1 below.

Table 1. *Three-year Average for Items Regarding Questions about Beliefs, Preferences, and Attitudes Toward People with Different Cultural Backgrounds* (n=23)

"These questions ask you about your beliefs, preferences and attitudes toward interactions and situations involving people who have different cultural backgrounds."		
Question	Pre 3yr Average	Post 3yr Average
I know the rules (e.g., grammar) of other languages.	3.37	4.21
I know the religious beliefs of other cultures.	4.16	4.42
I know the marriage systems of other cultures.	3.47	4.00
I know the rules for expressing non-verbal behaviors in other cultures.	3.53	4.11
I know the legal and economic system of other cultures.	3.63	4.37
I know the arts and crafts of other cultures.	3.68	4.42

I am conscious of the cultural knowledge I apply to cross-cultural interactions.	4.84	5.00
I check the accuracy of my cultural knowledge as I interact with people from different cultures.	5.21	5.27
I am conscious of the cultural knowledge I use when interacting with people with different cultural backgrounds.	5.05	5.53
I trust my cultural knowledge as I interact with people from a culture that is unfamiliar to me.	4.37	4.79
I alter my facial expressions when a cross-cultural interaction requires it.	4.42	4.42
I change my verbal behavior when a cross-cultural interaction requires it.	4.58	4.95
I change my non-verbal behavior when a cross-cultural situation requires it.	4.42	4.69
I use pause and silence differently to suit different cross-cultural situations.	4.27	4.69
I vary the rate of speaking when a cross-cultural situation requires it.	4.95	5.47
I enjoy living in cultures that are unfamiliar to me.	5.11	5.53
I am confident that I can socialize with locals in a culture that is unfamiliar to me.	5.26	5.53
I am confident that I can get accustomed to the life style in a different culture.	5.42	5.69
I enjoy interacting with people from different cultures.	5.89	6.16
I am sure I can deal with the stresses of adjusting to a culture that is new to me.	**5.84**	**5.58**

The second question posed a hypothetical situation where participants were asked to list competencies they would need to complete an international work assignment (Jesiek, 2011). Results are summarized in Table 2. Before engaging in the research abroad program, less than a third of all skills named were related to understanding the culture or language of the other country's employees (i.e., open-minded to learning the culture of foreign nations, familiarity with the area, language skills and/or access to a translator). In the post-tests for all three years, cultural knowledge, or sub-categories of cultural knowledge, were named as one of the

competencies necessary to complete the work assignment. In 2014, the three competencies most cited were language skills, knowledge of the geographical location, and appreciation for and knowledge of the new culture. In 2015, the four competencies which emerged were cultural knowledge, openness to the new culture, language skills, and cultivation of local work connections. In 2016, three competencies were cited: cultural knowledge, knowledge of local industry, and communication skills. Table 2, below, shows the skills participants named both in the pre- and post-tests.

Table 2. *Emergent Codes for Pre- and Post-test Item about Global Competency Skills* (n=23)

"Imagine you are an engineer working for a multinational corporation that is expanding operations in both South America and Southeast Asia. You are involved in evaluating the feasibility of the expansion, including finding suitable locations and planning operations. How prepared are you to enter this work situation? What knowledge and capabilities do you have and what do you lack?"		
Year	Pre-Test	Post-Test
2014	Open mind; a good attitude; communication skills; technical skills	Language skills; knowledge of the geographical location; appreciation for and knowledge of the new culture
2015	Language skills; flexibility; cultural knowledge	Cultural knowledge; openness to the new culture; language skills; cultivation of local work connections
2016	Open mind; communication skills; knowledge of current businesses in the geographical area	Cultural knowledge; knowledge of local industry; communication skills

The third set of questions had participants indicate their agreement with four statements related to self-efficacy in international research. All three years, the students' level of "anxiety or nervousness about tasks that are related to success as a professional that will conduct international research" decreased after their study abroad research programs (Pre Mean=2.80, Post Mean=2.68). All three years, the participants' post-test level of agreement for "I have had the opportunity to watch and work with others and have seen them perform tasks that I will need to perform in order to succeed in an international research environment" were higher (Post Mean=4.32) than their pre-test level (Pre Mean=3.73) of agreement. After their research abroad, participants also increased their agreement that they have received positive feedback about tasks they expect to need to perform in the future to succeed in an international research environment (Pre Mean=4.03, Post Mean=4.34).

When asked to rate themselves against their peers on 12 items related to international research skills, participants increased their self-rating on half (numbers bolded) and decreased their self-rating on the other half. The scale was from well below average (1) to well above average (5), with the average rating registering as a three. It should be noted that for all items on which participants decreased their post-test self-rating, they never rated themselves below average. All pre- and post-test means were still above average. See Table 3 below for data points.

Table 3. *Three-year Average for Pre- and Post-test Items Regarding Self Rating of International Research Skills* (n=23)

"Please rate yourself in comparison to peers on the following items."		
Item	Three Year Pre-Test Average	Three Year Post-Test Average
Understanding of how cultural differences may impact the research process	3.74	3.58
Understanding of the ethical implications of research	3.74	**3.89**
Ability to manage a project that is interdisciplinary in nature	3.63	**4.05**
Ability to manage a project that has team members from different cultures	3.53	**3.74**
Overall project management skills	3.79	3.63
Ability to find resources on a topic	3.58	3.47
Ability to synthesize resources from different sources	3.68	3.58
Ability to design research experiments	3.26	**3.79**
Ability to carry out research experiments	3.53	**3.89**
Ability to create and deliver effective academic presentations	3.79	3.63
Ability to write academic papers	3.37	**3.63**
Ability to work in teams effectively to solve problems	3.90	**3.95**

Discussion

Findings point to several interesting insights as related to the program goals of creating engineering students that are globally competent and are confident in their skills to conduct international research. Across cohort years the quantitative data indicates that students perceive an increased ability to conduct international research. Students reported more confidence in their research skills in general such as conducting, designing, and carrying out research experiments as well as how to work with teams comprised of individuals from different cultures. Students' international research self-efficacy increased over the course of the summer as well with students

indicating that the opportunity allowed them to watch and engage in hands-on international research activities that might help them to be successful if presented with future opportunities. From the quantitative data, it also appears that participants may have identified areas of weakness or research skills on which they needed to continue to work. For instance, participants decreased in their self-rating of their ability to create and deliver effective academic presentations and ability to find and synthesize relevant sources for their research projects; this could possibly indicate that students originally overestimated their abilities and corrected their estimation as they reflected on their actual research experiences.

One particular finding deserves further exploration. When asked to rate whether their "Understanding of how cultural differences may impact the research process" students actually reported a drop in their understanding after participating in the IRES program. This finding from the survey data runs counter to the open-ended responses that students provided. We speculate that this may be due the fact that the IRES program is carried out in the UK, an English speaking foreign country. Cultural differences may not have been as obvious given parallels in language and culture in the US and UK.

The qualitative data supports some of these findings and offers additional insights. Open-ended responses indicate that IRES participants realized that cultural knowledge was a key component that would be needed to complete an international work assignment. Themes that emerged in the comparison between open-ended pre/post responses indicate that basic knowledge of a foreign language and an understanding of social-cultural norms would be helpful as they engage in research and designing solutions with international collaborators. Having an immersive seven-week experience in a foreign country seemed to create new insights among the participants about what skills would be needed to navigate the complexities of international research projects.

While our results indicate that the program structure and overall experience is helping engineering students develop global competencies and international research skills our study does have limitations. Given the low number of participants, we were not able to run detailed statistical analyses. As the program continues to involve additional students, it may be possible to conduct t-tests to look at differences between pre/post scores. Also, the IRES program involves both undergraduate and graduate students. Our study did not look at differences in student development between these groups. Future studies could look to see whether there are differences between these student groups and what factors lead to those differences. In addition, future studies could also explore the differences between male and female participants. Despite these limitations, findings suggest that the IRES program could serve as a model for other engineering programs that are looking to develop global competencies and international research skills among their students. The 10-week experience has been shown to facilitate an understanding among participants of the influence that socio-cultural norms can have on the research process and international collaborations to design solutions.

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