Why Invest in International Research Experiences for Undergraduates?: Intercultural Maturity in Domestic and International REU Participants

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Impact on Student Learning: A Comparison of International and Domestic Undergraduate Research Experiences

1. Introduction

This paper presents the results of a study that examines how international and domestic undergraduate research experiences affect the intercultural maturity of students in science, technology, engineering, and mathematics (STEM) fields. This question is timely given the increasingly multinational nature of research collaborations. In its 2014 Science Indicators, the National Science Foundation (NSF) reported that 35% of U.S. articles published in 2012 were internationally coauthored, up from 32% in 2010, with U.S.-Japan coauthored papers comprising 7% of this total. Internationally coauthored papers in science and engineering now comprise one-fourth of all papers worldwide.[1] The percentage of U.S. papers published in 2012 with international coauthors was 35.9% in engineering and 45.8% in physics.[2,3] In its 2006–2011 fiscal year strategic report, the NSF acknowledged the importance of international research collaboration and identified as a key performance goal the need to "keep the United States at the frontiers of knowledge by increasing international partnerships and collaborations." The strategic plan went on to say, "As science and engineering (S&E) expertise and infrastructure advance across the globe, it is expected that the United States will increasingly benefit from international collaborations and a globally engaged workforce leading to transformational S&E breakthroughs."[4] However, as the number of science and engineering students participating in international education experiences remains small, there is a particular concern for the preparation of career researchers.

In response, U.S. universities are experimenting with new curricular methods, including the development of international programs designed for STEM students, to foster the development of skill sets necessary for successful international research collaboration. However, sparse research exists that comprehensively assesses globally focused outcomes associated with such efforts, and the simple question remains: Are international programs for STEM students effective in meeting these goals?

In this paper, we compare the experiences of students participating in two Research Experiences for Undergraduates (REU) programs funded by the NSF – the NanoJapan: International REU (IREU) Program and the Rice Quantum Institute (RQI) REU at Rice University. NanoJapan is a twelve-week IREU program through which twelve freshman and sophomore physics and engineering students complete cutting-edge research internships in the diverse fields of nanoscience and nanoengineering in laboratories at some of the best Japanese universities. The RQI REU is a ten-week domestic program in which twelve sophomore and junior students complete research internships with faculty at Rice University on quantum phenomena in atomic, molecular, solid-state, chemical, and biological systems. Our research identifies dimensions in which the IREU, as distinct from a domestic experience, may affect intercultural maturity, and suggests that the impact of the experience abroad may accelerate these gains.

2. REUs in Context

<u>2.1 The need for internationalization of STEM education</u>

The 2013 Open Doors report by the Institute for International Education (IIE) indicates that science and engineering students still make up a relatively small percentage of the overall number of students studying abroad. In 2011/2012, the last year for which data is available, only 3.9% of the students who studied abroad majored in engineering, 8.6% in the physical or life sciences, and 1.7%

in mathematics and computer science.[5]

These numbers are small, but universities are responding with programs designed to encourage greater participation in international education activities, prompted in part by changes in Accreditation Board for Engineering and Technology (ABET) accreditation outcomes that require engineering departments to show that they are providing students with "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context."[6] Several U.S. universities have created international programs that offer research experiences, including high-profile programs at Georgia Institute of Technology,[7] Purdue University,[8] the University of Rhode Island,[9] the University of California, San Diego,[10] and Worcester Polytechnic Institute.[11]

2.2 Domestic and international undergraduate research experiences

The National Council on Undergraduate Research defines undergraduate research as "An inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline" and identifies six key benefits of these experiences: a) enhancing student learning through mentoring relationships with faculty, b) increasing retention, c) increasing enrollment in graduate education and providing effective career preparation, d) developing critical thinking creativity, problem solving, and intellectual independence, e) developing an understanding of research methodology, and f) promoting an innovation-oriented culture.[12] The NSF has funded REU programs for many years in science and engineering fields at universities that are designed to "… support active research participation by undergraduate students …" and "… involve students in meaningful ways in ongoing research programs."[13] While the majority of REU programs' research is performed at domestic universities, some funding for international research is provided through specialized grant programs such as the International Research Experience for Students (IRES) or Partnerships for International Research and Education (PIRE) programs of the NSF. The goal of these international research programs is to support the "development of globally-engaged U.S. science and engineering students capable of performing in an international research environment at the forefront of science and engineering."[14,15]

A report on international research programs found that, in addition to the technical and professional impacts, the global or transcultural aspects of these experiences include: a) fueling the emergence of 'best practices' effective in sustaining transcultural collaborations, b) encouraging the innovative development of a 'shared work space' to accommodate cultural differences, c) developing and extending research communities beyond the U.S., d) increasing non-English language proficiencies, e) affirming the centrality and power of language, and f) contributing to solutions of the 'Global Grand Challenges'.[16]

Despite these benefits, there remains a need for more assessment of specific outcomes. A workshop report issued by Sigma Xi regarding how to assess international research experiences specifically identified as a necessary research agenda the need for studies that examined the motives for a scientist's or engineer's desire for international collaboration, including the relationship to education and career development. The report also called for studies to assess the impact of international collaboration on the careers of scientists and engineers at all stages.[17]

2.3 Theoretical framework: intercultural maturity

In addition to providing students with technical research skills, a goal of international research experience is to prepare students to work effectively as part of cross-cultural research collaborations. Deardorff notes that in STEM fields, this is most commonly referred to as global competency, but is alternatively referred to as cultural competency, multicultural competency, intercultural maturity, cross-cultural adaptation, cross-cultural awareness, or intercultural sensitivity. It assumes that particular knowledge, skills, and attitudes can be developed or learned and is evidenced by individuals' "effective and appropriate behavior and communication in intercultural situations."[18]

Our research is grounded in the Developmental Model of Intercultural Maturity proposed by King and Baxter Magolda.[19] They frame their work in the context of Kagen's concept of self-authorship,[20] or the ability to define one's beliefs, identity, or social relationships, and assume, like Kagen, that intercultural learning is an ongoing process that integrates three dimensions – cognitive, intrapersonal, and interpersonal dimensions:[21]

> "Demonstrating one's intercultural skills requires several types of expertise, including complex understanding of cultural differences (cognitive dimension), capacity to accept and not feel threatened by cultural differences (intrapersonal dimension), and capacity to function interdependently with diverse others (interpersonal dimension)."[22]

Cognitive development addresses how people think about diversity or multiculturalism. It includes cultural knowledge, or an understanding and awareness of various cultures and their impact on society, and an ability to use cultural context to evaluate what is known or valued. *Intrapersonal development* considers how an individual becomes more aware of and integrates his or her personal values into a sense of identity. This dimension is evidenced by a student's sense of self-direction in life, awareness of his or her strengths, values, personal characteristics, and sense of self. It is also evidenced by respect for and acceptance of cultural perspectives that are different from his or her own and a degree of emotional self-assurance in encounters with other cultures. *Interpersonal development* is concerned with how willing an individual is to interact with people from different social and cultural backgrounds, accept others, and be comfortable when relating to others. King and Baxter Magolda argue that educators are most effective at promoting intercultural maturity by considering how to encourage growth along these three developmental dimensions.[23]

Glass notes that our contemporary understanding of how students learn intercultural maturity assumes that students develop through social interactions with others as members of groups, organizations, and cultures.[24] In other words, experiences such as IREUs that challenge students to interact with people from different cultural or social backgrounds may affect their growth in the three dimensions of intercultural maturity.

3. Description of the Study

3.1 Research Experiences for Undergraduates

We selected the NanoJapan: International Research Experiences for Undergraduates (NanoJapan IREU) and the RQI Research Experiences for Undergraduates (RQI REU) programs for comparison because both programs are funded by the NSF, headquartered at Rice University, recruit participants from universities nationwide via a competitive selection process, enable students to participate in cutting-edge research in fields related to nanoscale and atomic-scale systems, phenomena, and devices, and require participants to present topical research posters on their summer projects at a summer research colloquium as a capstone experience.

The NanoJapan: IREU Program, the key educational initiative of the NSF PIRE grant awarded to Rice University in 2006, is a twelve-week summer program through which twelve freshman and sophomore physics and engineering students from U.S. universities complete research internships in the multidisciplinary field of nanoscience and nanoengineering in leading Japanese laboratories.[25] The program was awarded five years of funding in 2006 and received a five-year renewal in 2010 with funding confirmed through 2015.[26] Within this PIRE grant, the research projects conducted by NanoJapan students are concerned with various aspects of nanoscience and nanoengineering, ranging from synthesis of nanomaterials through nanodevice fabrication to a variety of electrical, magnetic, and optical characterization measurements.

NanoJapan recruits high-potential first and second year physics and engineering undergraduates. Before beginning their research internships, students complete a three-week orientation program in Tokyo that combines 45 hours of Japanese language instruction, an orientation to Japanese life and culture, and a series of introductory seminars on solid state physics, quantum mechanics, and nanoscience. During the eight-week research internship period, each NanoJapan student is integrated into an existing PIRE international research project in a Japanese partner's laboratory, under the mentorship of an English-speaking Japanese graduate student or post-doctoral researcher and under the co-advisement by their Japanese host professor and a U.S. PIRE professor. This structure gives NanoJapan students experience working as part of a true international research collaboration and, over the course of the summer, in learning to successfully navigate not only differences in approaches to research in the U.S. and Japan but also language and cultural barriers within their research laboratories in Japan. In addition, they must develop skill sets necessary to overcome logistical barriers, such as time differences, to enable them to remain responsive and engaged with all members of the PIRE international research team. Throughout the summer, NanoJapan students complete weekly reports on topics related to their research and the cross-cultural experiences in their laboratories.

The learning objectives for the NanoJapan IREU are: a) to cultivate an interest in nanoscience as a field of study among college students, b) to cultivate the next generation of graduate students in nanoscience, c) to add to the skill set of active nanoscience researchers, d) to create students who are internationally savvy and have a specific interest in and knowledge of Japan, and e) to educate students in culture, language, and technology, in order that they will be more effective when addressing global scientific problems. The program has been nationally recognized by both the National Academy of Engineering[27] and the Institute of International Education[28] as a best practice in the expansion of international opportunities for STEM students.

The RQI REU was the first REU program at Rice University and has been in continual operation since 1996 with funding confirmed through 2014.[29] The program provides highly promising undergraduate students with an opportunity to train during the summer in an intense, interdisciplinary, and collaborative research environment and involves them in a variety of discussions and interactions with faculty, post-doctoral researchers, and graduate students. Students from schools nationwide spend 10 weeks at Rice, working on cutting-edge, fundamental research projects on quantum phenomena in physical, chemical, and biological systems under the advisement of RQI faculty fellows. In addition, each student is expected to attend special seminars and group discussions for REU participants, make a report of the project, and participate in the RQI Annual Summer Research Colloquium at the end of the summer.

Participating students are frequently recruited from populations traditionally underrepresented in

STEM fields and from schools with limited research experiences and resources. The objectives of the program are for students to: a) acquire the capability of reading and understanding advanced scientific publications, b) understand and experience how to bring a research project to a successful completion, c) be able to successfully present their work to an audience, and d) understand principles for ethical and responsible research.

3.2 Methods

NanoJapan participants in Summers 2012 and 2013 and RQI REU students in Summer 2013 completed pre- and post-program assessments using the Georgia Institute of Technology International Internship (GITII) survey, a valid and reliable instrument developed to assess students' general knowledge, abilities, and skills related to technical internships. The instrument was developed by the Georgia Tech Office of Assessment and uses an externally validated General Self-Efficacy Scale to assess an individual's ability to cope with stressful life events.[30] We selected this instrument as one of the assessment tools for NanoJapan because it is specific to technical internships and allows comparison with a referent group of STEM majors participating in an international research internship, in this case through the Georgia Tech International Plan. The instrument is divided into three sections. In the first section, students rate items related to knowledge, abilities, and skills on two measures: i) how important they consider the item (on a 5-point scale from 'very important' to 'not important') and ii) their assessment of their relative preparation (on a 5-point scale from 'very well prepared' to 'not prepared'). In the second section, students are asked to assess their confidence in their workplace skills and abilities (on a 4-point scale from 'exactly true' to 'not true at all'). The final section asks students about their career plans.

The demographics of the NanoJapan IREU and RQI REU students were similar. Twenty-four students participated in the NanoJapan program (12 students in Summers 2012 and 2013, respectively) and 12 students participated in the RQI REU program in 2013. The 24 NanoJapan participants consisted of eighteen men and six women; at the time of participation, seventeen students were under twenty years old, six were between 20 and 29 years old, and one student was greater than 30 years. The RQI REU participants were seven men and five women; at the time of participation, four students were under 20 years old, seven were between 20 and 29 years old, and one student was older than 30 years.

3.3 Scale development and analyses

We first mapped items from the GITII survey into measures of cognitive, intrapersonal, and interpersonal development, using King and Baxter Magolda's definitions for each dimension. We started with 51 items and had two independent raters sort the items into one of the three dimensions of intercultural maturity or into a separate category for research skills. Twenty-three items mapped directly to the model of intercultural maturity; the items that were excluded were more closely related to general workplace preparation. The two raters discussed their decisions and resolved any discrepancies. The final sets of items are presented in Table 1 (see Appendix).We next computed the mean value for each category both for pre- and post-program assessments. For each category, we used students' responses to items asking their assessment of their relative preparation on individual items, their confidence in their workplace skills, and their intentions to participate in future international activities.

We use Chronbach's alpha, α, to indicate an acceptable level of internal consistency among the items included in each of the four composite scales. The obtained values of α were .76, .78, .77, and .87, respectively, for the four categories. As shown in Table 1, the Cognitive Development category consists of 6 items and uses responses associated with how students assessed their level of preparation; the extent of preparedness was assessed on a 5-point scale with anchors of 1 = ‘not prepared’ and 5 = ‘very well prepared’. The Intrapersonal Development category consists of 5 items and uses students' assessment of how accurately they consider the item to describe themselves; the extent of agreement was assessed on a 4-point scale with anchors of 1 = ‘not at all true’ and 4 = ‘exactly true’. The Interpersonal Development category consists of 6 items and uses responses associated with how students assessed their level of preparation; the extent of preparedness was assessed on a 5-point scale with anchors of 1 = ‘not prepared’ and 5 = ‘very well prepared’. The Technical and Research Skills category consists of 6 items and uses responses associated with how students assessed their level of preparation; the extent of preparedness was assessed on a 5-point scale with anchors of 1 = ‘not prepared’ and 5 = ‘very well prepared’.

4. Results

4.1 Intercultural maturity

The scales associated with intercultural maturity, i.e., the first three categories, are represented in the first three rows of Table 3 and Figures 1(a), 1(b), and 1(c) in the Appendix, respectively. The first scale measures cognitive development, which is associated with the ways in which individuals approach and evaluate intercultural knowledge, and how that knowledge is acquired and applied.[31] Both groups reported gains on post-program test scores, and indeed, demonstrated post-program test mean scores that were equivalent (PostM = 3.53, SD = .86). The NanoJapan students, however, rated their preparation at the beginning of the summer on items associated with cognitive development lower than the RQI students (NanoJapan: PreM = 2.82, SD = .67; RQI: PreM = 3.35, SD = .81), meaning that they reported greater positive change in their perceived ability to approach and evaluate intercultural knowledge at the end of the summer than the RQI participants. This difference between the two groups was significant; that is, on measures associated with cognitive development, the scores for NanoJapan students indicated greater positive change than their RQI counterparts between the completed pre- and post-program assessments; see Figure 1(a).

The second scale, intrapersonal development, which includes measures of self-awareness and a tolerance and interest in diversity, incorporated items in which students indicated their intention to engage in future international activities.[32] As shown in Table and Figure 1(b), the NanoJapan students scored higher than RQI students on both pre- and post-program assessments, and the RQI students indicated a small decline – NanoJapan: PreM = 3.20, SD = .53, PostM = 3.37, SD = .49; RQI: PreM = 2.43, SD = .84, PostM = 2.38, SD = .65. The difference between pre- and post-program test scores was not significant, nor was there any correlation between the program and the change in scores. In other words, NanoJapan students scored higher that RQI students on items associated with intrapersonal development both at the beginning and end of the summer. This may reflect an important difference between the students in these two programs. We know that students apply to NanoJapan because they are interested in an international experience, so it is perhaps not surprising that the NanoJapan students self-report, on both pre- and post-measures, that they are more likely to seek international experiences in the future.

The final dimension, interpersonal development, is characterized by a heightened awareness and capacity to engage in intercultural interactions that are interdependent, respectful, and informed by cultural understanding.[33] The RQI students scored higher than the NanoJapan students on the pre-program test (NanoJapan: PreM = 3.07, SD = .84; RQI: PreM = 3.07, SD = .37); see Figure 1(c). Both groups reported gains on post-program test scores, but those for the NanoJapan students were greater such that these students reported higher post-test scores than their RQI counterparts (NanoJapan: PostM = 4.18, SD = .53; RQI: PostM = 3.81, SD = .57). This difference between the two groups was significant, suggesting that the NanoJapan students experienced greater gains on interpersonal development as compared with the RQI students. This may reflect an important difference between the programs in that throughout the summer, the NanoJapan students completed a curriculum that required written updates and reflection exercises on not only their research projects but also intercultural issues and career preparation for science and engineering research.

4.2 Technical or research skill preparation

The scale measuring technical and research skills is represented in the bottom row of Table 3. It is characterized as the ability of the student to successfully design and conduct research within his or her discipline. For both the NanoJapan IREU and RQI REU groups, the post-program test scores were higher than the pre-program test scores. More specifically, for NanoJapan, the pre-test mean (PreM) value was 3.22 with a standard deviation (SD) of .82, which increased to a post-test mean (PostM) value of 3.77 with SD = .71. For RQI, an increase was observed from PreM = 3.74 (SD = .62) to PostM = 3.94 (SD = .49). The same data are also plotted in Figure 1(d) in the Appendix. There was no significant difference between the two groups in PostM values. This suggests that students in both programs perceived that they made gains with regard to skills associated with research in their respective disciplines.

5. Conclusions and Implications

5.1 Conclusions

This research identifies dimensions in which the international REU, as distinct from a domestic REU, may affect intercultural maturity, and suggests that the impact of the experience abroad may accelerate these gains. The intrapersonal dimension was the least robust, which may reflect the actual items in the GITII survey that were mapped to this scale. The items asked students to rate their likelihood to seek international experiences in the future. NanoJapan attracts students who are already interested in an international experience, so it is not surprising that at the end of the summer they report that they will consider study abroad, international travel, or working abroad in the future. These are students pre-disposed to seek experiences in which they will engage with people culturally different than themselves. The most we can conclude is that the experience abroad does not diminish students' interest in seeking international experiences.

On the cognitive dimension, however, while both students in the domestic and international REU demonstrated gains, the rate of perceived gains as expressed by NanoJapan students were greater. We know from qualitative interviews with NanoJapan alumni that they consider the experience of living and working in Japan to be as much of a personal challenge as the research itself.[34] The gains on cognitive measures, which include students' assessment of their readiness to apply their professional knowledge in cross-cultural settings, may reflect the NanoJapan students' sense of accomplishment of having not only successfully completed a cutting-edge research experience but also having done that in a challenging international setting. Simply put, the international dimension of the REU may be a catalyst for development of this dimension of intercultural maturity.

The interpersonal dimension presents the most interesting conclusions. NanoJapan students assessed themselves as less prepared than their RQI counterparts to engage cross-culturally at the beginning of the summer, and they indicated accelerated gains such that they rated themselves as better prepared than the RQI students at the end of the summer. There may be several factors that contribute to this. As with the intrapersonal dimension, this may reflect that the NanoJapan students are more self-confident at the end of the summer as a result of having successfully lived and worked for twelve-weeks in an international environment. This may also suggest that the NanoJapan curriculum, through which students are trained on intercultural communication and complete weekly written activities in which they reflect on cultural differences in their laboratories and assess their effectiveness in dealing with cultural challenges, indeed impacts students' development on this dimension of intercultural maturity. While the RQI students may have conducted research side-by-side with graduate students and researchers from around the world in their domestic laboratories, they did not participate in activities that required that they regularly complete written reflections on their experiences as part of an international or multicultural research team.

5.2 Implications

This study suggests that after completing either of the two REU programs, students assessed that their skills associated with the research itself had improved. Moreover, the international experience, as distinct from the domestic REU, did impact students' self-assessment on measures of intercultural maturity. This may be due in part to the challenge of living independently in Japan, but it may also be related to educational activities in which the NanoJapan students study and reflect on their experiences as part of an international research team. Research about learning outcomes from study abroad suggests that simply being immersed in an international setting is not sufficient for student learning – intercultural learning does not happen by asking students to 'sink or swim.' Rather, students make the greatest gains in intercultural learning when they engage with a cultural "interpreter" who is able to help students make sense of the new and different environment in which they are living and learning.[35] The three-week orientation and the weekly reflections submitted by NanoJapan students, with feedback from members of both the research and education team, may play that role for the IREU program. Undergraduate research programs that couple intercultural learning curricula with technical preparation for the research projects may be more effective in preparing students to be globally-savvy researchers.

5.3 Limitations and future research

This study involved a small population of students and used a single attitudinal measure in order to assess intercultural maturity. While the Georgia Institute of Technology International Internship Survey was mapped to dimensions of intercultural maturity, the items associated with the intrapersonal dimension reflected the least diversity in the types of cultural experiences in which students engage, yielding the least useful results. The results suggest differences between the groups that may be associated with differences in completing a domestic versus an international REU, which should be further examined using a larger sample and a combination of direct and indirect measures of intercultural effectiveness. Additionally, this study suggests reasons for the differences between groups that may be associated with students' ability to navigate challenges associated with living and working abroad generally and with educational interventions that prepare students for intercultural engagement. These reasons should be further investigated in that they have potential to have most impact on the design of other domestic and international REUs.

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6. Appendix

Table 1

Scale Items (Items that appear in the Georgia Tech International Internship Survey)
Cognitive Development
(An ability to) Synthesize and integrate knowledge across disciplines
(An ability to) Communicate in your host country's language in a professional setting
(An ability to) Communicate in your host country's language in a social setting
(An understanding of) The impact your professional practice has on society and culture
(An understanding of) The role of your discipline in solving global problems
(An understanding of) Your host country and their culture(s), beliefs, and values within a global and comparative context
Intrapersonal Development
I plan to work in a foreign country
I intend to participate in a study abroad experience
I will pursue/continue to pursue foreign language proficiency
I will work in a position of considerable international responsibilities
I will travel abroad for nonacademic or non-work related reasons
Interpersonal Development
(An ability to) Function on a multi-disciplinary or cross-functional team
(An ability to) Professionally collaborate with persons in your host country's workplace environment
(An ability to) Work effectively and efficiently in a cross-cultural environment
(An ability to) Practice your discipline in different social or cultural settings
(An understanding of) Professional and ethic responsibility within your discipline
(An understanding of) Effectively function in your host country's culture and society
Technical and Research Skills
(An ability to) Design and conduct experiments
(An ability to) Analyze and interpret data
(An ability to) Think critically and logically
(An ability to) Carry out projects independently
(An ability to) Identify, formulate, and solve problems within your discipline
(An ability to) Design a system, component, or process to meet desired needs and quality

Table 2 Correlation Among Scales

Scale	Cognitive Development	Intrapersonal Development	Interpersonal Development	Technical and Research Skills
Cognitive Development	(.41)	.09	.59	.35
Intrapersonal Development	-.08	(.73)	.49	-.08
Interpersonal Development	.68	-.01	(.30)	.32
Technical and Research Skills	.59	-.15	.66	(.62)

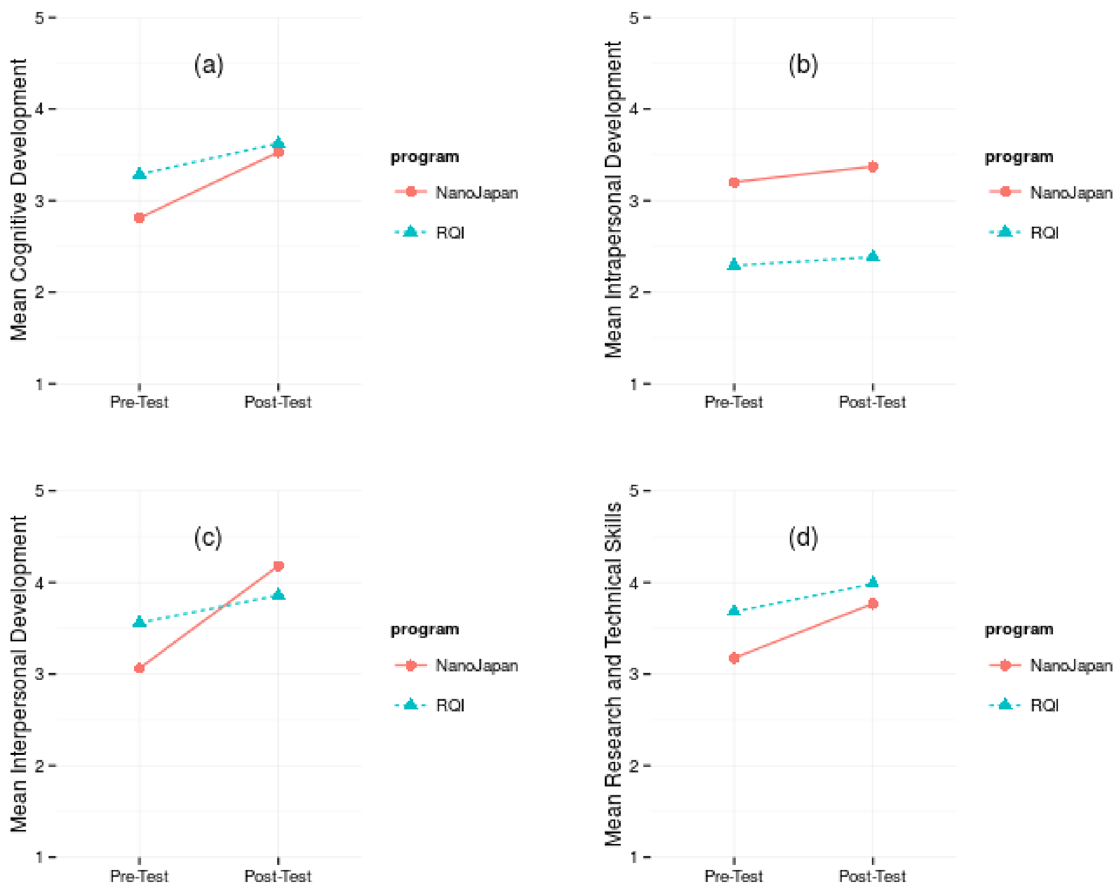
Note. Correlations between the pre-test scale scores are presented below the diagonal, correlations between the post-test scores are presented above the diagonal, and correlations between pre- and post-test scores for the same scales are presented along the diagonal.

Table 3
Means (*M*), Standard Deviations (*SD*), and Analysis of Variance (ANOVA) *F*-test Results for Cognitive, Intrapersonal, and Interpersonal Development, and Technical and Research Skills for the NanoJapan IREU and RQI REU Programs from Pre- and Post-program Self-Assessments

	Pre-test		Post-test		ANOVA *F*		
Dimension	*M*	*SD*	*M*	*SD*	Time (T)	Program (P)	T x P
Cognitive Development					11.70^{*}	1.31	$3.32^{\dagger}$
NanoJapan	2.82	.67	3.53	.86			
RQI	3.35	.81	3.53	.86			
Intrapersonal Development					1.46	21.05^{*}	1.34
NanoJapan	3.20	.53	3.37	.49			
RQI	2.43	.84	2.38	.65			
Interpersonal Development					49.60^{*}	.21	16.06^{*}
NanoJapan	3.07	.84	4.18	.53			
RQI	3.58	.37	3.81	.57			
Technical and Research Skills					16.71^{*}	2.19	2.07
NanoJapan	3.22	.83	3.77	.71			
RQI	3.74	.62	3.94	.49			

$^{*}p < .05$. $^{\dagger}p < .1$.

Figure 1. Mean scale scores as a function of time and program.



7. References

[1] National Science Board. "Academic Research and Development", *2014 National Science and Engineering Indicators,* 5-41 – 5-42, 2014. Accessed online on March 10, 2014 at http://www.nsf.gov/statistics/seind14/content/chapter-5/chapter-5.pdf.

[2] National Science Board. "S&E articles in engineering, by coauthorship attribute and selected country/economy: 1997–2012", *2014 National Science and Engineering Indicators,* Appendix Table 5-42, 2014. Accessed online on March 10, 2014 at http://www.nsf.gov/statistics/seind14/index.cfm/appendix.

[3] National Science Board. "S&E articles in physics, by coauthorship attribute and selected country/economy: 1997–2012", *2014 National Science and Engineering Indicators,* Appendix Table 5-45, 2014. Accessed online on March 10, 2014 at http://www.nsf.gov/statistics/seind14/index.cfm/appendix.

[4] National Science Foundation. "Empowering the National Through Discover and Innovation", *NSF Strategic Plan for Fiscal Years 2011 – 2016*, 8, (2011).

[5] Institute of International Education. "Fields of Study of U.S. Study Abroad Students, 2000/01-2010/11", *Open Doors Report on International Educational Exchange*, (2013).

[6] ABET. "Criteria for Accrediting Engineering Programs: Effective for reviews during the 2014 - 2015 accreditation cycle." 3, 2013. Accessed online on March 10, 2014 at http://www.abet.org/eac-criteria-2014-2015/.
[7] Lohmann, J. R., Rollins Jr., H. A., & Hoey, J. "Defining, developing and assessing global competence in engineers". *European Journal of Engineering Education, 31*(1), 119-131 (2006).
[8] Hirleman, E. D., Groll, E. A., & Atkinson, D. L. "The three axes of engineering education". Paper presented at the Proceedings of International Conference on Engineering Education, 8 pages, ICEE, Coimbra, Portugal. (2007). Available at https://globalhub.org/resources/73
[9] Grandin, J. M. "Launching a program in international engineering", Paper presented at the *Proceedings of the Seventh Annual Eastern Michigan University Conference on Languages for Business and the Professions*, Ypsilanti, MI (1998).
[10] Arzberger, P., Wienhausen, G., Abramson, D., Galvin, J., Date, S., Fang-Pang, L., Shinji, S. "Prime: An Integrated and Sustainable Undergraduate International Research Program", *Advances in Engineering Education, 2*(2), 1-34 (2010).
[11] DiBiasio, D., & Mello, N. A. "Multi-Level assessment of program outcomes: Assessing a nontraditional study abroad program in the engineering disciplines". *Frontiers: The Interdisciplinary Journal of Study Abroad, 10*, 237-252 (2004).
[12] National Council of Undergraduate Research. "Fact Sheet". Accessed online on March 10, 2014 at http://www.cur.org/about_cur/fact_sheet/.
[13] National Science Foundation, "Research Experiences for Undergraduates (REU)". Accessed online on March 6, 2014 at http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5517&from=fund.
[14] National Science Foundation. "International Research Experiences for Students". Accessed online on March 10, 2014 at http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12831.
[15] National Science Foundation, "Partnerships for International Research and Education." Accessed online on March 6, 2014 at http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12819.
[16] Y. Chang and E. D. Hirleman. "Summary and Recommendations", *Proceedings of the International Research and Education in Engineering (IREE) 2007 Grantees Conference:*, April, 2008. Available at https://engineering.purdue.edu/GEP.
[17] Sigma Xi, Developing evaluation approaches to international collaborative science and engineering activities. (2008). Research Triangle Park, NC: Sigma Xi.
[18] Deardorff, D. K. "Assessing intercultural Competence." *New Directions for Institutional Research,*149, 65-79 (2011).
[19] King, P. & Baxter Magolda, M. "A developmental model of intercultural maturity," *Journal of College Student Development*, 46, 6, 71-592, (2005).
[20] Kegan, R. *In over our heads: The mental demands of modern life.* Cambridge, MA: Harvard University Press (1994).
[21] King, P. & Baxter Magolda, M. "A developmental model of intercultural maturity," *Journal of College Student Development*, 46, 6, 71-592, (2005).
[22] Ibid, p. 574
[23] Ibid
[24] Glass, C. "Educational experiences associated with international students' learning, development, and positive assessment of campus climate," *Journal of Studies in International Education*, 16, 3, 228-251 (2011).
[25] National Science Foundation, "PIRE: U.S.-Japan Cooperative Research & Education: Ultrafast and Nonlinear Optics in 6.1-Angstrom Semiconductors", OISE 0530220, 2006. Accessed online on March 6, 2014 at http://www.nsf.gov/awardsearch/showAward?AWD_ID=0530220
[26] National Science Foundation, "PIRE: U.S.-Japan Cooperative Research and Education on

Terahertz Dynamics in Nanostructures", OISE 0968405, 2010. Accessed online on March 6, 2014 at http://www.nsf.gov/awardsearch/showAward?AWD_ID=0968405.

[27] National Academy of Engineering. "Infusing Real World Experience Into Engineering Education", pg. 33 (2013).

[28] Institute of International Education. "2008 Heiskell Award Winners: Study Abroad". Accessed online on March 6, 2014 at http://www.iie.org/Who-We-Are/IIENetwork-Membership/Heiskell-Awards/Study-Abroad/2008-Rice-Tulsa.

[29] National Science Foundation, "REU Site: Rice Quantum Institute", PHY 1156542, 2012. Accessed online on March 6, 2014 at http://www.nsf.gov/awardsearch/showAward?AWD_ID=1156542.

[30] Gordon, J. "Georgia Institute of Technology: Assessing Global Learning, Lessons from the Field." NAFSA: Washington, DC (2013).

[31] Engberg, M. "The influences of study away experiences on global perspective taking," *Journal of College Student Development,* 54, 5, 466-480 (2013).

[32] King, P. & Baxter Magolda, M. "A developmental model of intercultural maturity," *Journal of College Student Development*, 46, 6, 71-592, (2005).

[33] Ibid.

[34] Matherly, C., Phillips, S., Brooks, E., and Yamada, M. "A U.S. And Japanese student outlook on the impact of international research internships", *Third International Symposium on Terahertz Nanoscience, Honolulu*, Hawaii, December 10 – 12, 2012.

[35] Vandeberg, M., Connor, J., Paige, R. M., "The Georgetown Project: Interventions for student learning abroad," *Frontiers: The Interdisciplinary Journal of Study Abroad,"* 18, 1-75, (2009).