The Impact of a Summer Research Experience on Undergraduate Science Majors

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Abstract

Scholars and educators alike have noted the importance (and also the dearth) of international study programs for undergraduate science students and this article reports the impact of one such program. U. S. alumni of an international summer research program for Chemistry undergraduates completed an online questionnaire measuring their perceptions of the effectiveness of the program. The questionnaire items were based on stated program goals and the Model Assessment Practice (MAP) framework, developed by the Institute for the International Education of Students (IES). Overall, the results suggest that the program was very effective as an applied international experience, affording students the opportunity to acquire global science knowledge, international teamwork leadership skills, and sophisticated knowledge of scientific methodologies. Moreover, many of the students reported that their program´s experience was directly related to their subsequent academic and professional achievements. The results also revealed the importance and the challenges of language study in the training of internationally competent scientists. Implications of the results for application and future research are also discussed.

Key Words: international, global, language, education, adaptation, communication, students, science.

Introduction

> The development of science, perhaps more than the development of any other product of human culture, is international. No one society, no one nation or continent can claim credit for the development of science; it is the product of a glorious interwoven fabric of different civilizations, each of which has contributed something to its development.
>
> Frank H. T. Rhodes, 1997

While a study abroad experience has been described as integral to a quality liberal arts undergraduate experience, international experiences for undergraduate science majors have been less common (Guest, Livett, & Stone, 2006; O'Brien, 1995). According to the Institute for International Education, only 7.3% of U. S. study abroad students are science majors, whereas 33% are social science or humanities majors (*Open Doors*, 2010). Yet many scientists and educators recognize the importance of international experience for science students, as the practice of science grows increasingly globalized. Many discoveries—from DNA structure, to earthquake prediction, to projects in the Antarctic—have resulted from international cooperation. As Rhodes (1997, *n.d.*) notes "The best science is likely to flourish within a healthy variety of different cultural assumptions and competing viewpoints. The future of science is likely to benefit from the diversity of people and debate."

This essay reports the results of a study that evaluated one international program for undergraduate Chemistry majors—the Research Experience for Undergraduates (REU) sponsored by the National Science Foundation. In this particular REU program, U. S. American students spend one summer working in French research labs, conducting their own research project, but also working on collaborative research with French scientists. The following sections present a rationale for the importance of study abroad to science-based curricula, then provide a brief history of international Chemistry programs, describe the REU experience and evaluation project, and discuss the implications of this study for other international science programs.

Theory in Review

The Scientific Community and Study Abroad

An undergraduate international experience for science majors benefits the individual students, their colleges and universities, and the wider scientific community. Scholars and practitioners alike agree on the value of international experience for all college undergraduates. Recent research has documented (and touted) the benefits of these experiences including: increased knowledge of other cultures (Hammer, 2005), world geography, cultural relativism and global interdependence (Paige et al., 2009; Kitsantas, 2004; McCabe, 1994; Sutton & Rubin, 2004); increased cultural awareness, sensitivity and cross-cultural skills (Paige et al., 2009; Black & Duhon; 2006; Gray, Murdock, & Stebbins, 2002; Kitsantas, 2004; Sutton & Rubin, 2004; Hammer, 2005). Other benefits are increased friendships with people from different cultures and greater intercultural networks (Hammer, 2005). There are personal benefits for study abroad students as well, including increased self-confidence, maturity, and adaptability (Black & Duhon, 2006; Dwyer & Peters, 2004; Gray, Murdock, & Stebbins, 2002; Immelman & Schneider, 1998; Gmelch, 1997). Effects of study abroad seem to be quite enduring, impacting personal and professional development years after the international experience (Akande, & Slawson, 2000; Dukes, Johnson, & Newton, 1991; Dwyer, 2004; Dwyer & Peters, 2004).

Scientific endeavors are influenced by specific cultural contexts. By participating in overseas science programs, undergraduate science students gain not only general cultural knowledge and personal benefits identified above, but they also gain an awareness of the social and cultural contexts that dictate the priorities and approaches to science around the world. By learning about various approaches to science in the local setting, they increase their "ways of connecting their external and local knowledge, frequently in unexpected and very effective combinations" (DeWinter, 1997, p. 3).

Experts agree that in order to produce an internationally competitive and globally-informed workforce of scientists, international expertise should begin early in the students training, not just at the PhD or postdoctoral level (Carter, 2004). It is often too late to begin after one has completed the PhD and taken on numerous professional and personal responsibilities. Globalization has produced fundamental changes in the cultural composition of the world workforce and scientists and nonscientists alike now need twenty-first century skills; they need to be able to build and work in international teams (Salisbury et al., 2009; Covey 1997), they need effective multicultural team management and leadership skills of multicultural team leadership--which requires an understanding of cultural norms and values (Lisak & Erez, 2009; Adler, 1995; Hofstede, 1999; Stanek, 2000).

DeWinter (1997) notes that scientists may become world leaders and so must have access to the same opportunities enjoyed by other students—to develop a global perspective and address the fundamental problems of the world by combining theory and practice, learning and service. Most professionals, including scientists, are increasingly expected to combine in their career both technical knowledge and general education with some knowledge of a foreign language and intercultural skills (Nielson & Nielson, *in press*). Vaz (2000) concurs: "Our students will occupy workplaces and communities that have been transformed by globalization; they must learn to make connections across disciplinary, national, and cultural borders….." (p. 31).

In addition to benefits for individual students, international programs for undergraduates also benefit the academic institutions in helping to internationalize campuses. Returning students bring new perspectives to traditional curriculum, international programs provide opportunities for faculty to gain international expertise, and provide opportunities for collaboration with colleagues overseas (Gray, Murdock, & Stebbins, 2002; Vaz, 2000). Finally, the larger scientific community also benefits from undergraduate student participation in international study and particularly from participation in collaborative research projects. Students can bring intellectual curiosity to the scientific enterprise and help build scientific and technological capacity for the future.

DeWinter (1997) gives the example of undergraduate and graduate students conducting research on the habitat and behavior of the jacana (birds) in the tropical forests of Panama—not only expanding their knowledge of evolutionary biology, animal science, botany and the methods of scientific research, but bringing enormous vitality to the project, interacting with scientists from all over the world and building their and our scientific capacity for the future.

However, science educators and academic institutions have been slow to advocate for the importance of international experience for science undergraduates and undergraduates themselves have been reluctant to participate. Scholars and educators alike note this seeming conundrum; on the one hand, scientific research and scholarship spans national boundaries through international collaboration. On the other hand, science undergraduates receive less training in international contexts and less preparation for working in global teams than their humanities counterparts. O'Brien (1995) suggests that the root of the paradox may lie in the uniqueness of undergraduate science education, noting that science majors perceive their curriculum as more intensive, rigorous and demanding than other majors; secondly, they feel that the lockstep approach of their curriculum—the tight sequencing of their coursework—leaves them little time for exploring other course material or educational experiences like study abroad. Guest, Livett, & Stone (2006) found that at their university, science students, compared to students in arts, commerce, engineering and law, were the least likely to participate in international exchange programs. While the science professors surveyed had a high degree of international academic experience and noted the importance of this experience in motivating and stimulating their career interests, and in contributing to their professional success, they were less enthusiastic about supporting compulsory international experience at the undergraduate level. Guest et al. (2006) go on to advocate for the importance of international study for science majors, arguing that science students *should* see undergraduate student exchange as "normal".

Many educators have also noted the importance of application in overseas student experiences, that students learn most from applied, hands-on experience (Laubscher 1994) whether as part of academic curriculum, an internship program (Van Hoof, 2000) or in service-learning projects (Berry 2000; Lewis & Niesenbaum, 2005). Science students, especially, can benefit from experiential research activities, such as research projects that require them to engage in critical thinking both about their academic learning experiences and also their intercultural encounters (Guest et al., 2006).

International Chemistry Programs

There are several recent reports of successful science-related international exchange programs that take undergraduate students out of their familiar campus environments and make them engage other cultures in applied study—in China, India, Thailand, Germany, Mexico and other countries. For example, Carlson (2007) describes several engineering programs at the Worcester Polytechnic Institute, University of Rhode Island, and Purdue that provide students the opportunities to develop their engineering, language, and intercultural skills. He points out that, like science majors, engineering students travel abroad in disproportionately small numbers, and that future engineers need a "broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context". Andersen (2004) describes a similar program, the European Project Semester at the Copenhagen University College of Engineering where students work in multinational project teams learning team-building techniques, project management, international marketing, environmental subjects, cross cultural business behavior as well as foreign language studies.

Probably one of the first international programs for U. S. Chemistry majors was a "History of Science, Chemistry in Particular" course sponsored by Southern Illinois University in summer of 1971. Eighteen undergraduate and graduate Chemistry students toured Europe for 8 weeks, visiting 24 science museums in 6 European counties (Wotiz, 1972). Over the years other programs developed including the ERASMUS program and The TransAtlantic Science Student Exchange Program (TASSEP) (Wang, 2006) as well as the summer research exchange program between the Chemistry department at Leiden University (Netherlands) and a number of colleges and universities in the United States (Van der Gen, 1997). Recent reports suggest that Chemistry students are studying abroad in even greater numbers (Wang, 2006). Colleges and universities as diverse as Harvard, and Harvey Mudd College in Claremont California are helping students to experience face-to-face research collaborations in international settings. However, these (and other international undergraduate) programs are rarely systematically evaluated to determine if they indeed provide students the reported benefits of study abroad (De Wit, 1997; Immelman, & Schneider, 1998).

One recent program—The Research Experience for Undergraduate (REU)—was developed in large part to help meet the National Science Foundation (NSF)[i] goal of developing "a diverse, internationally competitive and globally-engaged workforce of scientists, engineers and well-prepared citizens" http://www.nsf.gov/pubs/2001/nsf0104/outcome.htm) and is the focus of this essay. The first author of this essay was contacted by the directors of the Chemistry REU program at the University of Florida Gainesville and asked to conduct an assessment of the ongoing program, to determine if the program goals were being met.[ii] In addition, a comprehensive online survey was distributed to all previous participants; this survey evaluated the overseas learning environment, resources and facilities available to the students overseas, students' mastery of scientific methodology and research skills in an international context.

Program description. The U.S./France REU Program, sponsored by the National Science Foundation, is one of 56 such programs that provide an international research experience for U. S. undergraduates. There is also a domestic counterpart program which provides research experience for international undergraduates in U. S. university centers. The particular U. S./ French REU program evaluated here was initiated in 1998 and is administered by the University of Florida Chemistry Department. Approximately 10 U. S. students are selected each year to work on joint research projects with French scientists in labs throughout France. A group of French students participate in a research experience at the University of Florida.

The specific goals of the U.S./France REU program are:

1) To provide participants with the opportunity to show creativity and **accomplish enough research** in 2-4 months to co-author a scientific publication.
2) To promote highly qualified students to **pursue graduate studies** and give them experience **to help them get jobs** after their degrees.
3) To foster a spirit of **cultural exchange and international interactions** early in the students' research careers (http://www.chem.ufl.edu/~reu/main/index_fr.html).

Methods

Respondents/REU Alumni

Attempts were made to contact all past U. S. participants of the France REU program, 1998-2003, through phone calls and emails and we were successful in contacting about 50% of them; approximately 70% of those contacted completed the online questionnaire. They were sent the URL address and link to the survey and completed it anonymously online.[iii]

Twenty REU alumni—about 30% of the total past participants (1999-2003)[iv]—responded to our online questionnaire. Of these respondents, 50% were women, 50% men; 15 were white, two were African American, one Asian Indian and two did not identify their ethnicity. They ranged in age from 23-29, with an average age of 25.7 years old. Most were either juniors (44%) or seniors (44%) when they went overseas to work on their research project in French chemistry labs: six went to Bordeaux, six to Paris, five to Strasbourg and one each to Lyon, Lemans, Montpelier, and Toulouse. Students came from a variety of academic institutions, about 1/3 were from large state universities (e.g. University of Florida), 1/3 from smaller public institutions (e.g. University of Richmond) and 1/3 from small private colleges (e.g. Pacific Lutheran University). While the number of respondents is relatively small, they appear to be fairly representative of the total alumni group, in terms of age, ethnicity, the date of their REU experience, and location, so we are confident our results represent the total REU experience.

[i] The National Science Foundation (NSF) is an independent federal agency created by the United States Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…" With an annual budget of about US$5.92 billion, it is the funding source for approximately 20 percent of all federally supported basic research conducted by colleges and universities in the United States (http://www.nsf.gov/index.jsp)

[ii] Two reports evaluating the ongoing summer programs were submitted to NSF and are available upon request from the first author.

[iii] The survey was posted on surveymonkey.com—a survey (questionnaire) template that can be customized for specific research projects.

[iv] There was only one respondent from 1998 so we included her/his questionnaire with the 1999 group. The breakdown in years were: 5 students from 1999, 4 students from 2000, 5 students from 2001, 4 students from 2002, 3 students from 2003. Two students reported that they had participated in two different REU programs.

Questionnaire Development

After reviewing the extant literature on study abroad outcomes and consulting with the REU study abroad administrators, we adapted the Model Assessment Practice (MAP) framework, developed by the Institute for the International Education of Students (IES). The MAP framework has been used in various studies assessing study abroad impacts (Black & Duhon, 2006; Dwyer & Katz, 2003). The MAP framework focuses on four areas: (1) the student learning environment (2) resources for academic and student support (3) student learning and the development of intercultural competence and (4) program administration and development.

Student learning environment. This dimension refers to the quality of experience available to the student at the international location. This category bridges the classroom and the local environment, to assure that students draw the full benefit from studying in another culture. The items in this category covered the students' associations with their French lab colleagues and their French "advisor." Items here also measured the opportunities they had to meet people and make friends in their location and the amount of cultural and scientific exchange they experienced, as well as the opportunities they had to visit other French chemistry labs.

Resources for academic and student support. This dimension refers to the resources that provide a high quality learning environment and includes: housing, transportation, health, and research support facilities. First, students were asked to assess their housing, the convenience of laundry, their satisfaction with food, medical coverage and treatment, and local transportation and extracurricular travel. Secondly, they were asked to assess the research support facilities, including: access to computer, lab and research facilities, the amount of lab time, the quality and level of lab experiments and guidance provided by their research "advisor."

Student learning assessment and intercultural development. The REU program administrators had two goals for the students: (1) The development of students' intellectual and research abilities and (2) intercultural skills. To measure the first goal, students were asked to assess the degree to which the REU experience helped them improve in their overall intellectual knowledge, including their general scientific knowledge, research methodology knowledge and skills, and how much the program helped them academically and professionally. Students were asked to assess the degree to which REU provided specific research preparation, including preparation to conduct scientific work in an international context, to work in an international research team, and to present their research in an oral presentation and prepare a research manuscript for publication. Finally, they were asked to assess the value of their particular research project in their academic and professional future. In order to assess the students' culture learning, they were asked to assess their satisfaction with their ability to acquire language proficiency, adjust to new customs and to deal with homesickness.

Program administration. In this category, students were asked to report their satisfaction with administrative procedures like application procedures, timeliness of notification of acceptance, amount of scholarship money, contact with REU administrators before, during and after their sojourn in France. We also asked the alumni a few general questions about their experience: we asked them to rate the program as a whole (on a 5 point scale) and asked them to list the three best things about the REU program and the 3 most challenging things.

Results

The REU alumni/respondents' overall evaluation of the program was very positive. That is, 83% of the respondents rated the program "Excellent" or "Very Good." Concerning their specific evaluations: On a five point scale (1=poor, 5=excellent), they indicated a mean satisfaction rating of 2.06 (SD = .87). That is, more than 70% of them indicated that they "strongly agreed" or "agreed" that the program was well organized. Concerning the value of the international component of the program, 90% of the respondents "strongly agreed" or "agreed" that the international component of the program added value to the underlying scientific experience (M=1.47, SD=.80). When asked to describe in their own words "three strengths of the program" the responses of the alumni were very consistent and very positive.

Almost all spoke specifically to the cultural opportunities afforded them by REU: Typical responses included: "First class immersion into a different culture & society" and "the opportunity to interact with people from another culture in their culture." Others mentioned the opportunity to travel, "seeing places you only see in books or movies." Several mentioned the opportunity of learning how to adapt to a new culture. The alumni were also consistent in describing the scientific benefits of the program. There seemed to be three themes: Learning how research is done in another culture; the opportunity to work with world class scientists (e.g., "opportunity to identify with a true group, especially in the international sense of building relationships with contemporaries in foreign countries"); and the benefits of the research itself (e.g.," exposure to graduate level thought and research, providing research experience for undergraduates that is vital to their success as grad students").

The strength of the program that emerged in these students' assessment statements is its integrated aspect--the fact that this program provides the opportunity for doing science in an international context, thus combining learning about science *while* gaining an international perspective (insights about new cultures, people, and places) early in their career. When asked to identify the three major challenges of the program, the responses again were very consistent: the language barrier was mentioned most frequently, then the challenges of "doing the science," and the third challenge was adapting to different ways of doing research. They also mentioned the pressure to "yield good research results to justify being selected for the program." Finally, adapting to the French culture was mentioned fairly often, a few mentioned being homesick and feeling lonely.

Student Learning Environment

In order to assess the effectiveness of the REU learning environment, alumni were asked to rate, on a five point scale (1=strongly satisfied, 5=strongly dissatisfied) their satisfaction with aspects of the program that could facilitate or inhibit their scientific learning in the context of cultural and professional interactions.

Table 1

Alumni Satisfaction with the Student Learning Environment

N=20

	Mean[a]	**SD**
People's cooperation in labs	1.50	0.62
Amount of cultural exchange	1.59	0.71
Opportunities for meeting people	1.61	0.70
Contact with French advisor	1.88	1.11
Amount of scientific exchange	1.88	0.49
Contact with French counterparts	2.12	0.99
Acceptance into lab groups as a contributing member	2.17	0.92

[a]1=strongly satisfied, 5=strongly dissatisfied

As shown in Table 1, in general, they were very satisfied with the lab workers' cooperation, their work with the French advisors and the amount of cultural and scientific exchange that they experienced. The mean scores on all these items were between 1.5 – 2.0, indicating high satisfaction. The only score above 2.0 (showing only slightly less satisfaction) was contact with their French counterparts and their acceptance into lab groups as a contributing member. This may be related to their lack of proficiency in the French language. They described these challenges in the following ways: "Being taken seriously by European scientists", "difficult to establish a successful advisor-advisee relationship in a short time", and "Assimilating to the way research is conducted in a foreign culture".

Resources for Academic and Student Support

The REU alumni were also asked about aspects of the program that could facilitate or inhibit their academic learning. That is, they were asked to rate, on a five-point scale (1=strongly satisfied, 5=strongly dissatisfied) their satisfaction with two kinds of resources 1) Logistical (travel, transportation, food, housing, laundry facilities, medical treatment/coverage) and 2) Research facilities support.

Table 2
Alumni Satisfaction with Academic and Student Support Resources (Logistical Support)
N=20

Logistical Support	**Mean[a]**	**SD**
Extracurricular travel	1.31	0.79
Local transportation	1.50	0.71
Transportation to and from France	1.67	0.77
Food	1.72	0.96
Housing location	2.06	1.34
Housing cleanliness	2.11	1.23
Housing safety	2.00	1.13
Medical treatment/coverage	2.15	0.99
Laundry convenience	2.44	1.24

[a]1=strongly satisfied, 5=strongly dissatisfied

As shown in Table 2, the questionnaire data revealed that students rated the logistics of the program pretty high. Perhaps not surprisingly, their highest satisfaction was with their extracurricular travel (M = 1.31), their local transportation (M = 1.50) and transportation to and from France (M = 1.67). They were also very satisfied with the food (M = 1.72). They were fairly satisfied with their housing, including location (M = 2.06), housing cleanliness (M = 2.11) and housing safety (M =2.00), and fairly satisfied with medical treatment/coverage (M = 2.15).

Table 3
Alumni Satisfaction with Academic and Student Support Resources (Research Resources)
N=20

Research Resources	**Mean[a]**	**SD**
Level of difficulty of lab experiment	1.71	0.59
Quality of experiments	1.82	0.39
Availability of computer support	1.78	0.88
Availability of access to Internet	1.83	1.04
Availability of Research facilities for your project	1.78	0.65
Lab facilities in general	1.89	0.76
Research facilities in general	1.89	0.76
Amount of lab time	1.89	0.68
Guidance by French advisor	1.94	0.97
Guidance by French undergrad counterpart	2.50	0.93

[a]1=strongly satisfied, 5=strongly dissatisfied

Concerning the research support resources, alumni reported high levels of satisfaction. As shown in Table 3, they were most satisfied with: the level of difficulty of the experiments (M = 1.7), the quality of the experiments (M =1.8), availability of research facilities for their projects (M = 1.8), availability of computer support (M = 1.8) and Internet access (M =1.8). They were also satisfied with lab facilities (M =1.9), research facilities (M =1.9), the amount of lab time (M =1.9), and the guidance given by their French advisor (M =1.9). The mean scores on all these items were between 1.7 and 2.0. The only scores above 2.0 involved their satisfaction with the advice from their undergraduate French counterpart, and 50% of the respondents (N = 10) reported that they did not have undergraduate counterparts—so the question was not relevant to the majority of the alumni.

Student Learning

Three areas of student learning were assessed a) The development of students' intellectual abilities, b) Specific research preparation and c) Culture learning.

The development of students' intellectual abilities. The alumni reported many intellectual benefits from the program and described how these benefits impacted their professional and academic goals. They were asked to rate on a 7 pt scale how much the program benefited them academically (1=not at all, 7=a great deal). Their mean score on this question was 5.57 (SD = 1.10), which is extremely high.

Table 4

Alumni Assessment of Improvement in Intellectual and Research Abilities

N=20

	Mean[a]	**SD**
Improvement in research skills	3.80	0.94
Improvement in scientific knowledge	3.72	0.71
Knowledge of research methodology	3.72	1.02

[a]5=much improved, 1= did not change

As shown in Table 4, the REU alumni indicated that they clearly improved in three specific areas in learning how to accomplish research. [a 5 point scale: 1=did not change, 5=much improved]. Overall, they reported that they improved their research skills (M = 3.8, SD = .94), their general scientific knowledge (M = 3.5, SD = .71) and their knowledge of research methodology (M = 3.72; SD = 1.02)

Respondents were also asked to identify specific academic benefits in their own words. They spoke enthusiastically of the academic benefits. Two themes emerged: first, the benefit of having an integrated research experience early in their career. Typical responses included: "REU prepared me to work on an international team and prepped me for working with foreigners in my current lab." "I learned a great deal of chemistry through hands-on research experience." "The program provided experience in integrating into an unfamiliar research lab" "Scientifically I was just learning how to interact in a lab and it was good to get foreign experience before entering an American lab for three years."

Alumni also described how their REU participation helped further their educational goals: in helping them to clarify their academic focus, and leading to academic success and rewards in graduate school: "REU helped me decide what I was interested in focusing on in grad school." "The experience showed me I didn't want to do computational chemistry but wanted to further my studies anyway." "After the REU program, I was nominated to apply for a Rhodes scholarship, I was accepted to my first choice grad school, I have received many academic awards." "My (graduate) advisor and other potential advisors say that the REU, especially the international program, really stood out to them. It was quite instrumental in my getting accepted to graduate school and receiving funding."

When asked to describe the impact of REU on their professional development, they reported that the international experience helped them in two major ways. First, that the REU experience would look good on a resume and would help them get a good recommendation for graduate school and ultimately a job. Typical responses: "People really took note of my research experience when they noticed that it was abroad." "I think there is some prestige that goes along with participating international research at the undergraduate level and I was able to get a publication out of it, which really bolstered my resume."

Secondly, they noted the important insights into international collaboration that help immensely in furthering their professional goals, as one reported, "Science is an international collaboration, therefore having an experience like this enables one to establish new connections and develop their skills in interacting with people of different nationalities" And others echoed similar observations:

The exposure to the manner in which research is conducted in other parts of the world was eye-opening. Applied properly, the lessons were empowering. The experience led me to pursue a PhD overseas and to focus my future career to study and work at the intersection of science and foreign policy.

Specific research preparation. When asked about specific research preparation, REU alumni reported that the overall professional gains from the program were even higher than the educational benefits (M = 5.83 on a 7 point scale, SD = 1.125).

Table 5
Alumni Satisfaction with Specific Research Preparation
N=20

	Mean[a]	**SD**
Preparation to conduct scientific work in an international context	1.59	0.62
Preparation to work in an international research team	1.65	0.86
Academic value of their individual research project	2.19	0.75
Professional value of their individual research project	2.17	0.79
Preparation to publish in scientific journals	3.0	0.91
Preparation to deliver an oral presentation about their work	2.46	0.78

[a]1=strongly satisfied, 5=strongly dissatisfied

As shown in Table 5, the mean satisfaction score (1= strongly satisfied, 5=strongly dissatisfied) for "preparation to conduct scientific work in an international context" was 1.59 (SD = .62). Looking at the percentages, almost 90% reported that they were "strongly satisfied" (44%) or "satisfied" (44%) that the program prepared them to conduct scientific work in an international context. Similarly, the mean score for "preparation to work in an international research team" was also very high, at 1.65 (SD = .86). They also indicated their strong satisfaction with the academic and professional value of their individual research project, on a 5 point scale (1= strongly satisfied, 5=strongly dissatisfied), M = 2.19 (SD = .75) and M = 2.17 (SD = .79) respectively.

There was slightly less satisfaction with their preparation to publish in scientific journals (M = 3.0, SD = .91). Examining the percentages revealed that 22% of the alumni were satisfied, 33% reported mixed satisfaction and 11% were dissatisfied with their preparation in this area. They had similar responses when asked about their preparation to deliver an oral presentation about their work (M = 2.46; SD = .78); 33% were satisfied, but 28% had mixed evaluations.

Culture learning.

Table 6
Alumni Satisfaction with their Culture Learning
N=20

	Mean[a]	**SD**
Ability to adjust to new customs	1.54	0.71
Ability to deal with homesickness	1.71	0.92
Level of language proficiency	2.76	1.20

[a]1=strongly satisfied, 5=strongly dissatisfied

As shown in Table 6, in general the REU alumni seemed satisfied with their ability to adapt to various aspects of the French environment (adapting to new customs (M = 1.54, SD = .71) and dealing with homesickness (M = 1.71, SD= .920). However, the language barrier emerged as the least satisfactory aspect of their culture-learning experience (M = 2.76, SD = 1.20). This was noted in several different places in the questionnaire. The fact that none of the students spoke French going into the program and they received no language training seemed to inhibit the effectiveness of the total experience. As one student reported during an interview (reported in Kristjansdottir, 2003): "the experience of being misunderstood was frustrating, you know, I didn't know the words for something so I just walked away, avoided it. Sometimes they got angry and sometimes I got angry at myself." Furthermore, limited cultural language knowledge oftentimes led to misunderstandings and frustrations with French colleagues in the labs. One student said:

> People in my lab were more willing to try and speak with me…but if you would go outside…they weren't willing to help you figure out what you wanted. It's pretty important to be able to communicate with people in more ways than just language.

Administration of Program

Finally, although not a stated goal of the program, REU administrators requested that we assess the alumni satisfaction with various aspects of the program administration.

Table 7
Alumni Satisfaction with Program Administration
N=20

	Mean[a]	**SD**
Pre-trip information	1.89	0.76
Amount of scholarship money	1.94	0.73
Contact with REU organizers	2.17	0.79
Contact person in case of emergency	2.44	0.89
Debriefing after program	2.56	0.92
Timeliness of disbursement of funds	2.56	1.33

[a]1=strongly satisfied, 5=strongly dissatisfied

Concerning the program administration and contact with program organizers—as shown in Table 7, the respondents were most satisfied with: the pre trip information they received (M = 1.89, SD = .76). Almost 90% of them reported being "strongly satisfied" or "satisfied" with the information they received. And about 90% were "strongly satisfied" or "satisfied" with the amount of their scholarship funds (M = 1.94, SD = .72), and while 60% were satisfied with the disbursement, more than 25% were dissatisfied or "very dissatisfied" with the timeliness of the disbursement (M = 2.56, SD = 1.34). They were also fairly satisfied with their contact with the REU organizers (M = 2.17, SD = .78). They were less satisfied with the contact person in case of emergency (M = 2.44. SD = .89) and the debriefing after the program (M = 2.56, SD = .92).

Discussion

The results suggested that the REU program is a very successful program and in most ways, meets the general goals identified by the NSF—to develop an internationally competitive and globally-engaged workforce of scientists. The results also suggest that the program meets the three specific program goals identified earlier in the paper. That is, the program clearly encouraged these qualified students *to pursue graduate studies and gave them experience that helped them get jobs* later on. According to the alumni surveyed, this REU experience was essential to their later successes as graduate students and scientist professionals. Many of them reported that their REU experience was directly responsible for their subsequent academic and professional achievements. Interestingly, the same results were discovered in a long-term, comprehensive approach to assessing student learning outcomes from studying abroad, namely the GLOSSARI project (Georgia Learning Outcomes of Students Studying Abroad Research Initiative) that spanned 10 years. The researchers of the project documented the academic outcomes of study abroad across the 35-institution University System of Georgia. Ten years later they found that students who study abroad have improved academic performance upon returning to their home campus. The results warrant the conclusion that studying abroad does add value to a student´s academic achievements (Sutton & Rubin, 2004, p. 77). Consequently, these findings concur with the findings of current study.

In addition, the program clearly *fostered a spirit of cultural exchange and international interactions early in these students' research careers*. Almost to a person, the alumni were emphatic, in both qualitative and quantitative statements, about the value of cultural learning and opportunities to exchange research knowledge afforded by the REU experience. The only specific goal that was not clearly attained was the ability of the students *to co-author a scientific publication*. As noted, few of the students achieved this, but they were generally satisfied with their work on their specific research projects and their collaborative work with French scientists. While this goal was not immediately attained, the REU experience formed the foundation for their later academic and professional work, including publication successes. Overall, the results strongly suggest that the REU experience can serve as one model for the type of applied international experience needed by contemporary science students, one that affords the opportunities to acquire global science knowledge, international teamwork leadership skills, and sophisticated knowledge of scientific methodologies.

The results also show the importance and the challenges of language study in the training of internationally competent scientists. The alumni reported the tremendous handicap they felt in their inability to speak French. They identified this as the number one challenge of their REU experience. Language proficiency is not a requirement for participation in the program and there is no opportunity for students to learn the language as part of the REU program. The students, in their interviews and online surveys, described in detail how the lack of language skills diminished their academic and social progress during their stay in France.

As noted earlier, the majority of students who study and research overseas are humanities students, and their study of language is often taken for granted (O'Brien, 1995). There is some resistance to science students spending valuable time in language study during their college years; they are often discouraged from taking language courses. This dismissal of language training for science students in general is noted in the difference between B. A. and B. S. degrees. In many U. S. American colleges and universities, the B. A. degree awarded to students in humanities generally involves language training while a Bachelor of Science degree involves courses in statistics or computer skills.

However, the results of this study show the difficulty many of the students experience because of their level of French language proficiency. While many of their colleagues in the lab spoke English, students noted that their lack of French speaking skills inhibited their interaction with the French scientists in the lab and this inability was especially problematic outside the lab, in their interactions with other French people. Many educators would concur that facility in the host language is intimately connected to one's success in an overseas context, regardless of the particular focus of the sojourn. For example, empirical evidence shows a positive effect of language competence on cultural adjustment (Birman, 1994; Birman et al., 2002; as cited in Kang, 2006). Additionally, scholars have emphasized the importance of language and communication competence in being able to function effectively in a new culture (Furnham, 1993; as cited in Ward, Bochner and Furnham 2001).

Further, to be a competent intercultural communicator requires an embodied relation to one's speaking and communicating. Scholars have stressed the importance of language and communication competence in the intercultural adaptation process (Martin & Harrell; 1996; Kim, 2001), and some state that intercultural communication is the designation of the adaptation itself (e.g., Gordon 1973; Nagata, 1969; Spicer, 1968; as cited in Kim 2001). Moreover, numerous scholars argue that competence in intercultural communication and in the language of the host culture are vital for fulfilling everyday needs and thus obtaining a sense of well-being in cross-cultural adaptation (e.g., Noels, Pon, & Clément, 1996; as cited in Yang, Noels, & Saumure, 2006). Furthermore, many studies have shown that language effectiveness is crucial and is in fact the key element in effective intercultural communication (Deutsch & Won, 1963; Giles, 1977; Martin & Hammer, 1989; Morris, 1960; Selltiz, Christ, Havel, & Cook, 1963; Sewell & Davidsen, 1956: Ting-Toomey & Korzenny, 1989; as cited in Chen & Starosta, 2008). In addition, the GLOSSARI project researchers found out that students who interact frequently with native speakers will be advantaged over those who don´t. Thus the time spent speaking the host language was correlated with higher intercultural learning (Sutton & Rubin, 2004). What might be particularly useful for students of a specific skill-set would be learning what Dlaska (1999) calls Language for Specific Purposes (LSPs). Utilizing language that allows students to understand complex chemistry terms as well as specific questions and requirements in the host-culture language might potentially reduce some of the work-oriented adjustment stress these students report feeling.

Because they were not able to communicate in the French language, the U.S. students' feelings of isolation, loneliness, stress, boredom, and so on affected their interaction with the hosts and thus they developed limited to no relationship with the French people. This supports previous research regarding the importance of host culture language fluency in order to develop relationships with members of the host culture (Ward and Kennedy, 1993: as cited in Ting-Toomey, 1999). Conversely, sojourners' language incompetence has been directly related to psychological and psychosomatic problems such as lack of sleep, headaches. In addition, knowing "when to say what appropriately, under what situations" is crucial in adapting to the new culture (Krishnan and Berry, 1992; as cited in Ting-Toomey, 1999, p. 241). Numerous students complained that the lack of French language and communication competence accounted for many of the psychological problems including incompetence, low self-esteem, isolation, stress, and feeling of not belonging, anxiety, and even depression. This supports previous research that reports that lack of host communication competence is associated with psychological problems relating to sojourners' maladaptation (Gudykunst & Kim, 2003).

A study that examined how both self-construals and communicative competence in the language of host society contribute to the cross-cultural adaptation of international students to Canada demonstrated that English- and French-Canadians who were more confident in using the language of the other cultural group experienced better psychological adjustment (Noels & Clément, 1996: as cited in Yang, Noels & Saumure, 2006). Chinese students studying in Canadian universities who had more frequent contact with the Canadian society had better psychological adjustment (Noels & Clément, 1996; as cited in Yang, Noels & Samure, 2006).

Such psychological stress stemming from insufficient language skills also has an effect on the quality of the students' self-reported learning within the scientific realm. One might make the argument that the students' goal was to complete their own research project and to gain skills in working with an international team of scientists which begs the question: to what degree did their inability to speak French inhibit their meeting these goals?

Table 8

Pearson Product Moment Correlations between Language Proficiency and Improvement in Research Abilities

N=20

	r	**Sig**
Research methodology	-.298	.245
Scientific knowledge	-.112	.668
Research skills	-.335	.189

In order to answer this question, we computed correlations between the science skills and the language proficiency measure, as shown in Table 8. That is, we computed the relationship between the students' language proficiency and their self- reported improvement in research methodology knowledge, general scientific knowledge, and their specific research skills. It should be noted here that, due to the small number of participants and the variegated response patterns over time, the correlations discussed here do not show a statistically significant relationship—which was entirely expected. However, even with the small sample size, the negative relationship between language proficiency and all aspects of improvement in scientific learning is consistent across participants. As noted in Table 8, language proficiency is negatively correlated with improvement in research abilities: i.e., the lower the level of language proficiency, the less improvement reported in research method, skills, and scientific knowledge.

The strongest negative correlation occurs between the relationship between the level of language proficiency and the improvement in research skills ($r = -.335$); the second is between language proficiency and research methodology knowledge ($r = -.298$); the weakest is between language proficiency and improvement of scientific knowledge ($r = -.112$). Upon closer examination, this pattern of results can be interpreted as existing as a function of language proficiency to specificity of linguistic development needed; in other words, as the areas move from more general to more specific, the degree of linguistic preciseness needed to increase knowledge and understanding of the topic increases, thus leading to the increasing impact of language proficiency on the understanding of more specific forms of knowledge. After a certain point, such a negative relationship may also lead to a loss in confidence and ability to maneuver within and around an esoteric scientific community—and, indeed, the larger community of science labs as a whole.

Some science educators suggest that language is rather irrelevant to most international science collaboration; that is the "language"/methods of science are universal and English is used at almost all international laboratories and science laboratories (O'Brien, 1995). However, these results support that learning how to "do" science in an international context and acquiring intercultural skills that make one an effective member of an international team requires competence in the host culture and language. Consequently, language proficiency is the key to science students who study and work overseas. These studies discussed above demonstrate that competence in intercultural communication and in the language of the host culture is vital for satisfying everyday needs and obtaining a sense of well-being in the host culture. Thus, the REU students needed to be better prepared by studying the culture and learning the French language before working and studying in the French laboratories in France. In order to eliminate or at least minimize the feeling of incompetence, low self-esteem, isolation, and stress that affected the REU students' interaction with the French counterparts, and led to no or limited relationship with the French people, language preparation was in order.

Multiple studies report that being able to use the language of the host culture will reduce many difficulties experienced in the host culture (Yang, Noels & Saumure, 2006). The REU students in current study when asked to identify the three major challenges mentioned the lack of language skills and the inability to speak French as the number one challenge of their REU experience. The students' responses suggest that science undergraduates receive more training in international contexts, preparation for working in global teams including learning the host culture language before working and studying abroad.

In summary, while the results of this study show that structured international research programs at the undergraduate level can be very effective in helping young scientists gain the academic, professional and personal qualities needed to become leaders in the 21st century scientific community, more attention should be paid to the language challenges that accompany these training programs.

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