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International Research Experiences and Global Competency Development for Graduate Students in Engineering and Science

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Abstract

Challenges from globalization, population growth, and climate change require science, technology, and engineering (STEM) professionals to have global competency. However, the impact of international experiences on STEM students' development of these abilities has not been well studied. We assessed the effects of international research experiences in Latin America and the Caribbean (LAC) and Europe on the development of global competency for STEM graduate students from the United States. Research placements in LAC were generally field-based, involving interactions with community members, while placements in Europe were mostly lab-based. Surveys and interviews with participants before and after their trips revealed increases in intercultural abilities for students from all groups. Students who traveled to LAC had higher intercultural abilities before the trip but experienced smaller gains than their counterparts who traveled to Europe. Despite the value in community-based activities for students outside of university settings, more effort is needed to

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eliminate students' barriers to understanding communication styles in their host communities.

Keywords
STEM, global competency, intercultural abilities, Latin America, Europe

Introduction

Globalization has introduced new technological competition for science, technology, engineering, and mathematics (STEM) fields, requiring graduates to be prepared for global competitiveness (National Science Foundation, 2018). Also, population growth, economic development, and climate change have increased environmental pressures, decreasing air and water quality, and increasing environmental health disparities between the wealthy and the poor (Mihelcic et al., 2017; United Nations, 2020). Global pandemics have required virtual multidisciplinary collaborations among STEM professionals from different countries and cultures (Ndubuisi et al., 2022). These have magnified calls for STEM students to develop global competencies (Ayokanmbi, 2011; Hunter et al., 2006; Jesiek et al., 2014; Majewska, 2022; Mihelcic et al., 2017; Strong et al., 2020; U.S. National Academies of Sciences, Engineering, and Medicine (NASEM), 2021; U.S. National Research Council (NRC), 1985, 2012; U.S. National Academy of Engineering (NAE), 2004, 2021).

There is still no universally accepted definition of global competency (Ortiz-Marcos et al., 2020), but it has been described as "the capacity to examine local, global and intercultural issues, to understand and appreciate the perspectives and worldviews of others, to engage in open, appropriate and effective interactions with people from different cultures, and to act for collective well-being and sustainable development" (OECD, 2018). Globally competent STEM professionals should have "personal qualities, international knowledge, and technical skills required to work effectively in a range of international settings and work environments" (NRC, 1999). Specifically, they should have "language and cultural skills, teamwork and group dynamics skills, knowledge of the business and engineering cultures of counterpart countries, and knowledge of international variations in engineering education and practice" (NRC, 1999). Downey et al. (2006) defined global competency as the ability to "understand and work effectively with co-workers who are raised, educated, and living in countries other than their own and who solve and define problems differently than oneself". Cross-cultural competency has been described as "an individual's ability to function effectively in another culture" (Gersten, 1990), such as effectively approaching cultural differences and building relationships through interactions (Bird et al., 2010; Cotton et al., 2019).

The impact of international experiences on STEM students' ability to develop intercultural and global competencies has been examined (e.g., Casad et al., 2018; Jesiek et al., 2012; Manser et al., 2015; May et al., 2015; Mazzurco et al., 2020; Widmann & Vanasupa, 2008; Yu, 2012), but many studies had small sample sizes or lacked conclusive

findings. Furthermore, there is little consensus about which intercultural abilities to assess (Thompson & Jesiek, 2010), and which assessment strategies to use (Jesiek et al., 2018). Studies of students with international experiences (e.g., Shen et al., 2011) support the importance of these experiences on the development of global competencies. However, it remains unclear if all international experiences are equal, or if some experiences are more impactful than others. Nursing students who completed international experiences in developing countries developed similar competencies as students who traveled to industrialized countries (Haloburdo & Thompson, 1998; Maltby et al., 2016), however we are unaware of similar studies with STEM students.

Our study focused on the experiences of students who participated in a project funded by the U.S. National Science Foundation, the goal of which was to initiate a cultural shift in university programs toward developing international research competencies and building capacity through global partnerships. The program allowed graduate students to travel internationally to collaborate with institutions and community organizations in host countries, with the expectation that these international experiences would help students develop global competencies and function effectively in international settings. We hypothesized that student placements (e.g., Latin America, the Caribbean, Europe) might influence their outcomes.

Our goal was to uncover the effects of participation in these international experiences on students' development of competencies, specifically by addressing these questions: What types of intercultural abilities do students develop and how are they related to global competencies? Are there differences between the competencies and skills developed by students traveling to higher-income European countries compared to lower-income countries in Latin America and the Caribbean (LAC)? We used interviews and existing survey instruments to uncover the effects of these experiences on student outcomes, as described in policy documents (e.g., NAE, 2004, 2021; NRC, 1999, 2012; NASEM, 2021).

Methods

The overall project was headquartered at a university in the southeastern U.S., with international partners that included universities and community organizations in Europe and LAC. The project's overarching research question was "can effective, geographically appropriate, and culturally appropriate engineered systems be established that utilize wastewater as a resource for recovery of energy, water, and nutrients?" The project also had educational goals to initiate a cultural shift in individuals and university programs. One goal was to influence the shared set of values, beliefs, and assumptions related to mutually beneficial knowledge exchange, to catalyze the transfer of ideas and best practices for bidirectional information transmission, and to broaden participation in STEM fields.

During the first three years of the project, survey data were collected from 25 graduate students—80% studied civil or environmental engineering and 20% studied anthropology or marine science—the students participated in international experiences in: Belize, Bolivia, Costa Rica, Mexico, Czech Republic, the Netherlands, the United

Kingdom, or Italy. We also included students who traveled to the U.S. Virgin Islands, even though it is a U.S. territory. The international experiences lasted 1–2 weeks in most cases, though some students spent more than a month, and one student spent only a few days. For comparison, we included three students who traveled from academic institutions in European countries to the U.S., where they stayed for several months to more than one year.

We analyzed data in three groups based on students' home institutions and their international placements (Table 1) (Malik, 2013):

- Group 1 included students who traveled from the U.S. to LAC, in countries or regions that were less developed, with human development indices (HDI) that were generally less than or equal to 0.75.
- Group 2 included students who traveled from the U.S. to Europe, in countries with HDI greater than 0.85.
- Group 3 included students who traveled from European countries (HDI > 0.85) to the U.S.

We obtained institutional review board permission. Participants provided written consent.

Data Sources, Evidence, Objects, or Materials

Students completed a Communication Styles Survey (CSS) and a Motivations and Options and Intercultural Abilities Survey (MOIAS), both adapted from Fantini and Tirmizi (2006). The CSS was completed before the international experiences; both surveys were completed after the trip. The purpose of the CSS was to characterize students' beliefs about communication styles in their "home culture" and in the culture of their international hosts ("host culture"). Questions addressed social protocols, conflict situation, work, task, and foreign relationship. The MOIAS included questions pertaining to the beginning and end of the students' trips, allowing for paired samples, and included questions that helped understand the students' motivations toward the host culture, as well as their intercultural knowledge (6 questions), attitude (13 questions), skills (11 questions), and awareness (18 questions). Both surveys solicited responses on a five-point Likert-scale. There were more than 25 responses for the MOIAS because some students completed multiple international experiences.

Semi-structured interviews were also conducted with 16 participants using the International Research Experiences Interview Protocol, which included twenty-six open-ended questions related to the following categories: description of the work conducted; knowledge and skills developed; global competency; sustainability science and engineering (Mihelcic et al., 2003); effect of collaboration across disciplines; and comments and recommendations. These interview questions were developed based on the research questions that guided the project. The interviewees belonged to research groups with slightly different foci, but they worked together on the

Table 1. Location of Student Placements, Types of Experiences, and Housing Arrangements.

Group	Location[a]	Number of students	Types of experiences	Housing
Group 1: Students from the US academic institution traveling to Latin America and the Caribbean (LAC)	Bolivia Costa Rica Belize Mexico US Virgin Islands (USVI)[b]	3 4 4 1 1	- Doing engineering research - Participation in professional meetings - Interdisciplinary research: engineering & anthropology - K-12 curriculum development - Meeting with research partners - Training courses - Working with farmers	- With community members - Student housing - Hotel
Group 2: Students from the US academic institution traveling to European countries	Czech Republic Netherlands UK Italy	1 2 5 1	- Attending symposia - Doing engineering research - Taking classes	- Student housing - With family or friends
Group 3: Students traveling from academic institutions in European countries to the US	From Czech Rep. From the Netherlands	1 2	Doing engineering research Meeting with research partners	- Private housing

[a]The students are grouped by the location of the origin of their educational experiences and their destinations. This information does not represent the students' citizenship or ethnic origin.

[b]The US Virgin Islands (USVI) is a territory of the United States located in the Caribbean, so travel from the continental US to the USVI is not really an "international" experience. Nevertheless, we still chose to include it in this study because the student's research experience in the USVI involved collaboration with community members from different cultures and from different socioeconomic backgrounds (Jesiek et al., 2012).

overall project. Interviews were conducted before and after the students' international experiences.

Data Analysis

Using a mixed-method approach (Onwuegbuzie & Teddlie, 2003), we analyzed qualitative data with interpretational analysis (Gall et al., 2007) assisted by HyperResearch software. Quantitative data were analyzed by calculating the number of transitions per student, defined as the number of times a student changed the answer to a question by increasing or decreasing the Likert Scale score in the post-trip survey, relative to the pre-trip survey. Statistical tests were not performed due to small sample sizes and the diverse destinations and cultural backgrounds of participants.

Results

Results from the Surveys

Intercultural abilities. Overall, survey results indicated that the international experiences helped students expand their world vision and develop a better understanding about other cultures. Students changed their responses to questions from the MOIAS about intercultural competencies after their international stay. For example, when asked if students knew the "essential norms and taboos of the host culture" related to greetings, dress, and behaviors, seven of 27 respondents (26%) changed their answers from "unsure" at the beginning of their trip to "agree" by the end (Table 2). Students from Groups 1 and 3 changed their responses from "disagree" or "unsure" to a response of "agree" for these questions more frequently than Group 2 students. Group 1 students reported an increase along the Likert Scale in their responses about intercultural competencies more frequently than students from Groups 2 and 3 (Table 3). However, the magnitude of the increase was greater for Group 2 students (Figure 1).

All students reported increases in their intercultural knowledge, attitude, skills, and awareness after their international experiences (Figure 1), which is consistent with previous findings about engineering doctoral students who scored higher for intercultural competency on the Miville–Guzman Universality-Diversity Scale-Short form after international experiences (Main & Wang, 2020). Engineering student participants in a three-week study-abroad program to Guatemala increased their scores on intercultural sensitivity assessments after the trip (Merfeld-Langston & Elmore, 2017).

Our study adds the additional finding of differences between the students traveling to LAC vs. Europe (Figure 1). Compared to their colleagues from Group 2, students from Group 1 reported higher scores for intercultural knowledge, attitude, and awareness *prior to* their international experiences. These students also reported higher proficiency in the host communities' primary language prior to their international experience, with 78% of students from Group 1 reporting the ability "to speak with sufficient structural accuracy and vocabulary to participate effectively in most

Table 2. Response Modifications for the 48 Questions in the MOIAS Survey After the International Research Experience.

Changes in students' responses to questions about intercultural competency[a]	Average number of response modifications per student		
	Group 1: Students traveling from the US to Latin America and the Caribbean (LAC) (n = 15 surveys)[b]	Group 2: Students traveling from the US to Europe (n = 9 surveys)	Group 3: Students traveling from Europe to the US (n = 3 surveys)
From "Disagree" to "Agree" (increase)	1.0	0.5	1.7
From "Unsure" to "Agree" (increase)	6.0	3.4	6.3
From "Disagree" to "Unsure" (increase)	0.3	0.2	0
From "Agree" to "Disagree" (decrease)	0	0	0
From "Unsure" to "Disagree" (decrease)	0	0.2	0.3
From "Agree" to "Unsure" (decrease)	0.1	0.1	0

[a]Responses of "Disagree" and "Strongly Disagree" were grouped together; responses for "Agree" and "Strongly Agree" likewise were grouped together.
[b]The number of unique student surveys here is greater than the number of unique students shown in Table 1 because two students completed the survey twice for different trips

formal and informal situations" prior to the trip, compared with only 63% of students from Group 2.

The MOIAS also included questions about students' motivation toward the host culture, which indicated that more than half of the students reported wanting to return home "a little" or "not at all". More than half of the students had "high" or "extremely high" admiration for the hosts and a "high" or "extremely high" desire to get along with members of the host culture and adjust as best they could.

Communication styles. The CSS revealed that the international experiences allowed students to re-evaluate ideas about communication styles (e.g., social protocols, conflict situations, work tasks, professional relationships) in their host culture and their own culture. After the international experiences, students changed 51% of responses to questions in the CSS about their host culture's communication styles (Table 4). They reported being "not sure" for 37% of questions about host culture communication styles before the international experience, but they provided responses other than "not sure" for more than two-thirds of the same questions after the trip. While the

Table 3. Changes in Student Responses to the 48 Questions in the MOIAS Survey.

	Average number of changes in responses to the questions per student		
Changes in students' responses to questions about intercultural competency[a]	Group 1: Students traveling from the US to Latin America and the Caribbean (LAC) (n = 15 surveys)[b]	Group 2: Students traveling from the US to Europe (n = 9 surveys)	Group 3: Students traveling from Europe to the US (n = 3 surveys)
Increased	17.2 / 48	12.4 / 48	3.3 / 48
Decreased	0.3 / 48	0.2 / 48	0.7 / 48
Remained constant	30.4 / 48	35.4 / 48	44.0 / 48

[a]An increase is defined as an upward transition on the Likert Scale from the beginning to the end of the students' stay in the host country; a decrease is defined as a downward transition. Likert scores: 1 = strongly disagree; 2 = disagree; 3 = unsure; 4 = agree; 5 = strongly agree).
[b]The number of unique student surveys here is greater than the number of unique students shown in Table 1 because two students completed the survey twice for different trips

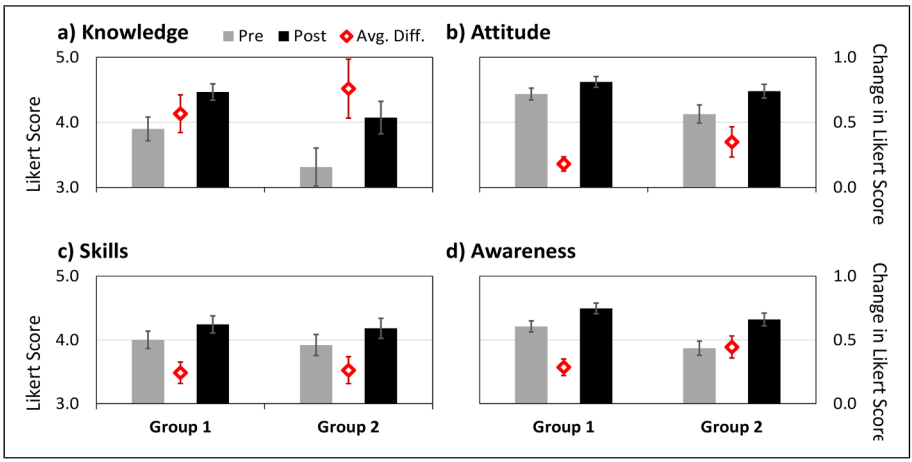

Figure 1. Changes in the students' intercultural (a) knowledge, (b) attitude, (c) skills, and (d) awareness, based on responses to questions in the MOIAS before (pre-) and after (post-) their international experience for group 1 (students who traveled from the us to Latin America and the Caribbean) and group 2 (students who traveled from the us to Europe). Avg. Diff. = average differences (changes) in the pre- and post-trip Likert scores (error bars show Studentized 95% confidence intervals), where 1 = strongly disagree; 2 = disagree; 3 = unsure; 4 = agree; 5 = strongly agree).

sample size was too small to perform comparative statistical analysis, there were no major differences observed between groups regarding the overall changes in responses to these questions.

Table 4. US Student Responses to Questions About the Communication Styles of People in the Students' Host Culture from the pre- and Post-Trip Surveys.

Change in response before and after trip	Group 1: Students traveling from the US to Latin America and the Caribbean (12 surveys; n = 256 paired responses)	Group 2: Students traveling from the US to Europe (7 surveys; n = 161 paired responses)
No change in response (were never unsure)	85 (33%)	72 (45%)
Changed response (but were never unsure)	35 (14%)	15 (9%)
Changed response from not sure to another answer	54 (21%)	51 (32%)
Changed response from one answer to not sure	41 (16%)	15 (9%)
No change in response (remained unsure)	41 (16%)	8 (5%)

There were, however, differences between groups in the students' levels of certainty. After the international experiences, Group 1 students reported being "not sure" about more questions than Group 2 students. Some Group 1 students reported using less English than Group 2 students, but differences in their certainty about communication styles may not have resulted from language barriers alone. Of four students from this group who reported language proficiency that was "equivalent to that of an educated member of the host culture," one never reported being "not sure" while others reported being "not sure" for 2, 8, and 21 out of 22 questions pertaining to the host culture in the post-trip CSS.

The students had diverse cultural backgrounds, self-described based on their nationalities or family heritage. Of 20 students who responded to the CSS, 14 described their cultural background as being "American" or related to the "USA" or "U.S." culture; the other six described their cultural background as a territory, country, or region located outside of the continental U.S., including South America, Africa, Europe, or the Caribbean. Nine students who identified as having "American" or "U.S." culture were from Group 1 and the other five were from Group 2. Group 1 students with "American" or "U.S." cultural backgrounds reported having higher language proficiency than Group 2 students with "American" or "U.S." culture, on average. Students in both groups with cultural backgrounds outside of the continental U.S. generally had higher language proficiencies than Group 1 students with "American" or "U.S." culture.

The sample was too small for statistical analysis (especially considering the diverse destinations within each group), however some results reflected differences in student outcomes based on their own demographics, cultural identities, or prior intercultural experiences. We did not assess students' prior international experiences, but several

students with cultural backgrounds from outside the continental U.S. were either "Colombian", "Puerto Rican", "Hispanic", or "Latin American", indicating possible prior experience interacting with LAC cultures. These students had international experiences in regions that were different from their own cultural identities, but their prior intercultural experiences could have influenced their outcomes.

Group 1 students with "American" or "U.S." cultural backgrounds reported being "not sure" about more questions after the trip than students with cultural backgrounds outside of the continental U.S. Specifically, for 10% of the questions answered by U.S.-culture students, the response was changed from "not sure" before the trip to another answer after the trip. For students with cultural backgrounds outside of the continental U.S., responses to 57% of the questions were changed from "not sure" before the trip to another answer after the trip.

One potential explanation for this difference is that the prior LAC cultural experiences of students in the latter group may have given them enough perspective before the trip to know that cultural norms in LAC can differ regionally (thus potentially leading them to be "not sure" about more questions before the trip), but enough cultural insight to understand host culture communication styles after the trip. On the contrary, students with U.S. cultural backgrounds may have had more preconceptions about cultural norms in LAC (thus potentially leading them to make assumptions about communication styles before the trip), but they responded "not sure" about host culture communication styles after the trip more frequently. For example, for the following questions about cultural norms in LAC host countries, all Group 1 students with LAC cultural backgrounds had perceptions about communication styles in the host culture after the trip (i.e., they did not answer "not sure"), but more than half of Group 1 students who identified with non-LAC "American" or "US" cultural backgrounds responded "not sure" to these questions after the trip:

- In work situations in the host culture, I believe they prefer information be: (a) presented first by clearly stating a purpose followed by logical and sequenced points; (b) presenting a lot of information that allows one to draw one's own conclusions; or (c) not sure
- When faced with a task in the host culture, I believe they prefer: (a) first to understand the big picture before working on individual parts; (b) to work on parts of the task without needing to know its relation to the whole; or (c) not sure
- In a difficult or embarrassing situation in the host culture, I believe they prefer to: (a) avoid saying anything that will embarrass either party; (b) discuss the issue in hopes of resolving it; or (c) not sure
- When speaking to superiors about a concern in the host culture, I believe they prefer to: (a) speak directly on one's own behalf; (b) express one's concern through an intermediary; or (c) not sure
- When the people of the host culture speak with others of different cultural backgrounds, I believe they generally: (a) adjust the type of eye contact they make

with them; (b) make the same type of eye contact they do with others of their own culture; or (c) not sure

All students changed fewer responses about communication styles in their home culture than for the host culture (Table 5). They never reported feeling "not sure" about communication styles in their home culture, but still changed 22% of their answers, suggesting that the international experiences also prompted self-reflections about communication styles in their own culture, which has been previously reported (Deardorff, 2006; Stier, 2006; Taylor et al., 2011). Group 2 students changed more answers about their home culture than Group 1 students, but the sample size was too small for statistical analysis.

Interviews revealed that the cultural differences and the depth of interactions between students and host country community members were greater for Group 1 than for Group 2 (see below). Considering this observation along with trends seen in the survey, we postulate that the combination of cultural differences and the depth of Group 1 student interactions with community members added complexity to their experience, causing them to develop competencies in different ways than Group 2 students.

Findings from Interviews

Content knowledge. Students reported improving their scientific knowledge about the effects of sea level rise in coastal settings, treatment of domestic and agricultural wastes, and the impact of tourism on water, sanitation, and health. They also reported improving laboratory skills and learning about differences in laboratory facilities and the ways research is performed in the U.S. compared to their host country.

Table 5. US Student Responses to Questions About the Communication Styles of People in the Students' Home Culture from the pre- and Post-Trip Surveys.

Change in response before and after trip	Group 1: Students traveling from the US to Latin America and the Caribbean (12 surveys; n = 256 paired responses)	Group 2: Students traveling from the US to Europe (7 surveys; n = 161 paired responses)
No change in response (were never unsure)	205 (80%)	120 (75%)
Changed response (but were never unsure)	51 (20%)	41 (25%)
Changed response from unsure to another answer	0	0
Changed response from one answer to unsure	0	0
No change in response (remained unsure)	0	0

Previous studies on STEM student outcomes in international research programs have also identified that the experiences helped students develop basic research skills. For example, Mladenov et al. (2016) reported that U.S. engineering participants in a six-week international research experience in South Africa gained research skills, improved their identities as engineers, and developed stronger intentions to pursue doctoral degrees. Bettez and Lineberry (2004) reported that engineering students who studied abroad improved their application of engineering skills to real-world problems, with greater gains in the development of "soft" skills than "hard" engineering skills.

Our results suggest that the international experiences in LAC may have helped students become more resourceful. All participants reported learning new methods, but students who traveled to LAC learned about different ways to complete laboratory tasks. For example, a student who studied wastewater reuse in agriculture learned to conduct analyses in the field and in laboratories with less equipment and materials. Another student reported learning to work with fewer laboratory resources by conserving and reusing materials. One student described research in their host country as "more practical" than the "more theoretical" research at their home institution.

Students who traveled to LAC worked more directly with community members, which is consistent with community-based participatory research (CBPR). The use of CBPR in engineering may expand the benefits of research to society by co-designing solutions in direct response to community needs (Montoya et al., 2021). These benefits were reported by participants in our study. For example, a student who traveled to Belize reported that interactions with community leaders helped them realize that their thesis idea did not suit the situation in their host community; so they shifted the focus of their dissertation to better align with community needs.

Field-based research also enabled students who traveled to LAC to learn about qualitative research methods. One engineering student who traveled to Costa Rica interviewed farmers and community members to obtain information about the operation and performance of a particular technology; the interviews also helped them learn about different ways wastewater was reused.

Students who traveled to Europe noted that research practice was similar to what they experienced in the U.S., but that their European hosts were more rule-bound and structured compared to the U.S. One student commented on the need to pay fees to "rent" lab space, which was not common at U.S. institutions. In comparison, students who traveled to LAC perceived the research culture as less structured and proceeding at a slower pace than in the U.S.

Knowledge about culture. Group 3 students reported that their integration into research groups with students from different countries gave them new social networks and collaboration skills, helping them work more effectively in partnerships. Group 2 students perceived host cultures to be similar to U.S. culture, but they still learned the importance of cultural understanding to work effectively in international settings. Group 1 students perceived host cultures to be different than their home culture, reporting that they

learned to be more open to different cultures. This effect has been previously reported for students who studied abroad. Haas (2018) reported strong associations between international study experiences and cultural awareness gains, specifically with increased knowledge about commonalities and differences between and within cultures.

Group 1 participants in our study had more experiences with community members than their colleagues in Groups 2 and 3. As such, they reported adapting their research according to the context and resources available, causing them to perceive a direct impact from their projects. They reported learning the importance of accounting for host culture during research conceptualization, and of understanding context and access to resources as factors that may impact technology adoption in different settings.

Language learning. Group 3 students reported improving writing, reading, and speaking abilities in their host country language, but Group 2 students lacked opportunities to develop language skills because most of their interactions were in English. Group 1 students' interactions with community members provided more language learning opportunities (Spanish language immersion in Costa Rica and Bolivia, learning Creole in Belize, and learning different English phrases used in the USVI). Students who were most immersed in host communities reported the greatest increases in language skills, learning technical words, regional vocabulary, and improving pronunciation–this effect was larger in LAC than in Europe.

Language proficiency could improve technical outcomes of international research experiences. Previous studies have reported that language barriers impeded learning outcomes. Omachinski (2013) found that engineering students studying abroad in Germany experiencing frustration and low interest to improve language skills, which interfered with their ability to learn. O'Connell and Resuli (2020) reported that language difficulties of Chinese engineering students studying in the U.S. impeded their communication with students and professors, affecting academic progress.

Global competency. Overall, the international experiences allowed students to develop global competencies. Group 1 students reported having opportunities to cultivate collaborations with host community partners, where they gained an understanding about differences between their culture and the host culture in terms of social dynamics, politics, resources, and cultural attitudes. They reported learning how to work with people of different ethnicities, socioeconomic statuses, and access to resources. They learned to recognize contributions of their host country colleagues and felt that they had the opportunity to "walk in other researchers' shoes." This helped them understand the importance of patience, especially in settings with fewer resources. They reported developing confidence to successfully pursue future international collaborations.

Limitations and Opportunities for Future Research

There are limitations to our findings. First, surveys were restricted to self-reported measures. The sample size of 25 participants, while larger than other studies, is still

rather small. The use of self-reporting with small sample sizes has been critiqued as a limitation (Haas, 2018). There is concern about potential impact of social desirability bias on self-report survey results, but limited evidence to support this concern (Miller, 2012). Despite this limitation, our results still provide new insights about potential differences between international research settings and student outcomes.

Our findings did not consider outcomes on host communities, which (Montoya et al., 2021) identified as a gap in the literature. There are many international university programs, which may have different impacts on participants and host communities. Melles (2018) found that student trips from an industrialized country to India with the intention to "help" people in poverty were characterized by inadequate community assessments and low participation by community members, leading to the commodification of poverty and the exotification of intercultural interactions. Our interview results indicated that students' engagement in research partnerships may have led to more effective, mutually beneficial outcomes. Nevertheless, future studies should include assessments of host communities in addition to student participants.

In our study, host nationalities were used to define groups (e.g., LAC vs. Europe) to analyze students' intercultural communication abilities. This is a limitation, as it is more consistent with the "culture-as-given" approach rather than the "culture-as-construct" approach (Handford et al., 2019). The latter avoids confounding culture with nationality by embracing complexities of culture (Handford et al., 2019). If our survey results are considered alone, then inference about *intercultural* abilities is purportedly drawn based on interactions with people of different *nationalities* (not cultures). However, our interviews addressed some of the complexities of students' interactions with host collaborators. We caution readers against oversimplifying our quantitative findings and advise readers to consider the complexities of these collaborations that were examined more closely through the interviews.

Conclusions

Our findings indicate that the students' international experiences were meaningful and transformative. Based on the MOIAS and CSS surveys, students increased their intercultural knowledge, skills, attitudes, and awareness because of the international experiences, and developed better understandings about the communication styles in their host countries. Furthermore, they changed their perceptions about communication styles in their own cultures. They developed awareness about the importance of collaborative partnerships, picked up language skills, and learned to work in settings with different access to resources, with researchers, scientists, professors, students, and community members who reportedly defined and approached problems in different ways. The students thus became more globally competent (as defined by Downey et al., 2006) because of their international experiences.

While all students gained some knowledge and skills, we found differences between students who traveled to European countries with higher HDIs and those who traveled to regions in LAC with lower HDIs. The latter group experienced more in-depth interactions

with their collaborators, which may have brought more attention to differences in culture and worldview through self-reflection. Nevertheless, students who traveled to Europe experienced greater gains in intercultural knowledge, skills, attitudes, and awareness than their counterparts who traveled to LAC regions.

Students who traveled to Europe did not interact as much with people outside of the university, where English speaking was the norm. Hammer et al. (2003) stressed that learning from experience does not occur simply because an individual is in the vicinity of events that occur, but rather because of complex constructions of cultural differences that lead to richer experiences. If helping students develop global competencies is a goal, then their placements ought to be conceptualized to provide opportunities to engage in meaningful work-related activities with community members outside of a university laboratory, and to intentionally engage in reflection.

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References

Ayokanmbi, F. M. (2011). Competencies for global engineers and technologists. *Journal of Industrial Technology*, *27*(1), 2–6. https://www.iastatedigitalpress.com/jtmae/article/id/14167/

Bettez, D. J., & Lineberry, J. T. (2004). Assessing engineering students' study abroad experiences. In Proceedings of the 2004 American society for engineering education annual conference & exposition, June 20–23 2004, Salt Lake City, UT, USA.

Bird, A., Mendenhall, M., Stevens, M. J., & Oddou, G. (2010). Defining the content domain of intercultural competence for global leaders. *Journal of Managerial Psychology*, *25*, 810–828. https://doi.org/10.1108/02683941011089107

Casad, B. J., Palomo, M., & Mladenov, N. (2018). International scientific research experiences: developing global citizens and nurturing engineers and scientists of the future. In Proceedings from the 2018 ASEE annual conference & exposition, Salt Lake City, UT, USA.

Cotton, D. R. E., Morrison, D., Magne, P., Payne, S., & Heffernan, T. (2019). Global citizenship and cross-cultural competency: Student and expert understandings of internationalization terminology. *Journal of Studies in International Education*, *23*(3), 346–364. https://doi.org/10.1177/1028315318789337

Deardorff, D. K. (2006). Identification and assessment of intercultural competence as a student outcome of internationalization. *Journal of Studies in International Education*, *10*(3), 241–266. https://doi.org/10.1177/1028315306287002

Downey, G. L., Lucena, J. C., Moskal, B. M., Parkhurst, R., Bigley, T., Hays, C., Jesiek, B. K., Kelly, L., Miller, J., Ruff, S., & Lehr, J. L. (2006). The globally competent engineer: Working effectively with people who define problems differently. *Journal of Engineering Education*, *95*(2), 107–122. https://doi.org/10.1002/j.2168-9830.2006.tb00883.x

Fantini, A., & Tirmizi, A. (2006). Exploring and assessing intercultural competence. *World Learning Publications*. http://digitalcollections.sit.edu/worldlearning_publications/1

Gall, M. D., Gall, J. P., & Borg, W. R. (2007). *Educational research: An introduction* (3rd ed.). Pearson Publications.

Gersten, M. C. (1990). Intercultural competence and expatriates. *The International Journal of Human Resource Management*, *1*(3), 361–369. https://doi.org/10.1080/09585199000000054

Haas, B. W. (2018). The impact of study abroad on improved cultural awareness: A quantitative review. *Intercultural Education*, *29*(5–6), 571–588. https://doi.org/10.1080/14675986.2018.1495319

Haloburdo, E. P., & Thompson, M. A. (1998). A comparison of international learning experiences for baccalaureate nursing students: Developed and developing countries. *Journal of Nursing Education*, *37*(1), 13–21. https://doi.org/10.3928/0148-4834-19980101-05

Hammer, M. R., Bennett, M. J., & Wiseman, R. (2003). Measuring intercultural sensitivity: The intercultural development inventory. *International Journal of Intercultural Relations*, *27*, 421–443. https://doi.org/10.1016/S0147-1767(03)00032-4

Handford, M., Maele, J. V., Matous, P., & Maemura, Y. (2019). Which "culture"? A critical analysis of intercultural communication in engineering education. *Journal of Engineering Education*, *108*(2), 161–177. https://doi.org/10.1002/jee.20254

Hunter, B., White, G. P., & Godbey, G. C. (2006). What does it mean to be globally competent? *Journal of Studies in International Education*, *10*(3), 267–285. https://doi.org/10.1177/1028315306286930

Jesiek, B.K., Buswell, N.T., & Zhu, Q. (2018, June 23–July 27). *Global engineering competency: Assessment tools and training strategies*. In 2018 ASEE Annual Conference & Exposition. Salt Lake City, UT, USA. https://doi.org/10.18260/1-2–30559

Jesiek, B. K., Shen, Y., & Haller, Y. (2012). Cross-cultural competence: A comparative assessment of engineering students. *International Journal of Engineering Education*, *28*(1), 144. https://www.ijee.ie/latestissues/Vol28-1/14_ijee2532ns.pdf

Jesiek, B. K., Zhu, Q., Woo, S. E., Thompson, J., & Mazzurco, A. (2014). Global engineering competency in context: Situations and behaviors. *Online Journal for Global Engineering Education*, *8*(1), 1. https://digitalcommons.uri.edu/ojgee/vol8/iss1/1/

Main, J. B., & Wang, Y. (2020). Intercultural competency among engineering doctoral students. *Studies in Graduate and Postdoctoral Education*, *11*(2), 181–196. https://doi.org/10.1108/SGPE-06-2019-0058

Majewska, I. A. (2022). Teaching global competence: Challenges and opportunities. *College Teaching*, 1–13. https://doi.org/10.1080/87567555.2022.2027858

Malik, K. (2013). *Human Development Report 2013: The Rise of the South: Human Progress in a Divided World*. Retrieved from New York. http://hdr.undp.org/sites/default/files/reports/14/hdr2013_en_complete.pdf

Maltby, H. J., de Vries-Erich, J. M., & Lund, K. (2016). Being the stranger: Comparing study abroad experiences of nursing students in low and high income countries through hermeneutical phenomenology. *Nurse Education Today*, *45*, 114–119. https://doi.org/10.1016/j.nedt.2016.06.025

Manser, N., Naughton, C., Prouty, C., Orner, K., Verbyla, M., & Mihelcic, J. R. (2015). Improving the global competency of graduate engineers through peace corps partnership and long-term international service. In 122nd American society of engineering education annual conference and exposition: Making value for society, Seattle, WA (pp. 1–18).

May, D., Wold, K., & Moore, S. (2015). Using interactive online role-playing simulations to develop global competency and to prepare engineering students for a globalised world. *European Journal of Engineering Education*, *40*(5), 522–545. https://doi.org/10.1080/03043797.2014.960511

Mazzurco, A., Jesiek, B. K., & Godwin, A. (2020). Development of global engineering competency scale: Exploratory and confirmatory factor analysis. *Journal of Civil Engineering Education*, *146*(2), 04019003. https://doi.org/10.1061/(ASCE)EI.2643-9115.0000006

Melles, G. (2018). Sustainable community development or voluntourism: Sustainable housing in rural Maharashtra. *Social Sciences*, *7*(12), 247. https://doi.org/10.3390/socsci7120247

Merfeld-Langston, A., & Elmore, A. C. (2017). The effects of a water-focused study abroad program on engineering students' intercultural communication competence. *Proceedings from World Environmental and Water Resources Congress*, 550–561. https://ascelibrary.org/doi/abs/10.1061/9780784480595.050

Mihelcic, J. R., Crittenden, J. C., Small, M. J., Shonnard, D. R., Hokanson, D. R., Zhang, Q., Chen, H., Sorby, S. A., James, V. U., Sutherland, J. W., & Schnoor, J. L. (2003). Sustainability Science and Engineering: The Emergence of a New Metadiscipline. *Environmental Science & Technology*, *37*(23), 5314–5324. https://doi.org/10.1021/es034605h

Mihelcic, J. R., Naughton, C. C., Verbyla, M. E., Zhang, Q., Schweitzer, R. W., Oakley, S. M., Wells, E. C., & Whiteford, L. M. (2017). The grandest challenge of all: The role of environmental engineering to achieve sustainability in the world's developing regions. *Environmental Engineering Science*, *34*(1), 16–41. https://doi.org/10.1089/ees.2015.0334

Miller, A. L. (2012). Investigating social desirability bias in student self-report surveys. *Educational Research Quarterly*, *36*(1), 30–47. https://eric.ed.gov/?id=EJ1061958

Mladenov, N., Palomo, M., Casad, B., Pietruschka, B., & Buckley, C. (2016). Authentic scientific research in an international setting as a path toward higher education. In AGU fall meeting abstracts, ED22A-06.

Montoya, L. D., Mendoza, L. M., Prouty, C., Trotz, M., & Verbyla, M. E. (2021). Environmental engineering for the 21st century: Increasing diversity and community participation to achieve environmental and social justice. *Environmental Engineering Science*, *38*(5), 288–297. https://doi.org/10.1089/ees.2020.0148

National Academies of Sciences, Engineering, and Medicine (2021). *Call to action for science education: Building opportunity for the future*. The National Academies Press. https://doi.org/10.17226/26152.

National Academy of Engineering (2004). *The engineer of 2020: Visions of engineering in the new century*. The National Academies Press.

National Academy of Engineering (2021). *Strategy 2021–2026. People. Systems. Culture*. National Academy of Engineering.

National Research Council [NRC] (1985). *Engineering education and practice in the United States: Foundations of our techno-economic future*. The National Academies Press.

National Research Council (1999). *Meeting the challenge of global engineering. Chapter 6 of engineering tasks for the new century: Japanese and U.S. perspectives*. The National Academies Press. https://doi.org/10.17226/9624

National Research Council (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*. Committee on Defining Deeper Learning and 21st Century Skills, J.W. Pellegrino and M.L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. The National Academies Press, Washington, D.C., USA.

National Science Foundation (2018). *Building the Future: Investing in Discovery and Innovation*. NSF Strategic Plan for Fiscal Years 2018–2022. Document No. NSF18045. https://www.nsf.gov/pubs/2018/nsf18045/nsf18045.pdf

Ndubuisi, A., Marzi, E., Mohammed, D., Edun, O., Asare, P., & Slotta, J. (2022). Developing global competence in global virtual team projects: A qualitative exploration of engineering Students' experiences. *Journal of Studies in International Education*, *26*, 259–278. https://doi.org/10.1177/10283153221091623

O'Connell, R. M., & Resuli, N. (2020). Academic challenges for Chinese transfer students in engineering. *Journal of International Students*, *10*(2), 466–482. https://doi.org/10.32674/jis.v10i2.674

OECD (2018). *Global competence for an inclusive world*. Organization for Economic Cooperation and Development (OECD), Directorate for Education and Skills, Paris, France. https://www.oecd.org/education/Global-competency-for-an-inclusive-world.pdf

Omachinski, K. M. (2013). Communication and cultural implications of short-term study-abroad experiences on engineering students. *Connexions: International Professional Communication Journal*, *1*(2), 43–77. ISSN 2325-6044.

Onwuegbuzie, A. J., & Teddlie, C. (2003). A framework for analysing data in mixed methods research. In A. T. C. Teddlie (Ed.), *Handbook of mixed methods in social and behavioral research* (pp. 351–383). Sage.

Ortiz-Marcos, I., Breuker, V., Rodríguez-Rivero, R., Kjellgren, B., Dorel, F., Toffolon, M., Uribe, D., & Eccli, V. (2020). A framework of global competence for engineers: The need for a sustainable world. *Sustainability*, *12*(22), 9568. https://doi.org/10.3390/su12229568

Shen, Y., Jesiek, B. K., & Chang, Y. (2011). Cultural orientation and global competency: A comparative assessment of engineering students. In Proceedings of the annual conference of the American society for engineering education, Vancouver, Canada, June 26–29.

Stier, J. (2006). Internationalisation, intercultural communication and intercultural competence. *Journal of Intercultural Communication*, *11*(11), 1–12. https://immi.se/oldwebsite/nr11/stier.pdf

Strong, M. H., Burkholder, G. J., Solberg, E. G., Stellmack, A., Presson, W. D., & Seitz, J. B. (2020). Development and validation of a global competency framework for preparing new

graduates for early career professional roles. *Higher Learning Research Communications*, *10*(2), 67–115. https://eric.ed.gov/?id=EJ1279834 https://doi.org/10.18870/hlrc.v10i2.1205

Taylor, G., Papadopoulos, I., Dudau, V., Maerten, M., Peltegova, A., & Ziegler, M. (2011). Intercultural education of nurses and health professionals in Europe (IENE). *International Nursing Review*, *58*(2), 188–195. https://doi.org/10.1111/j.1466-7657.2011.00892.x

Thompson, J., & Jesiek, B. (2010). Assessing the intercultural competence among sophomore mechanical engineering students: Baseline data and analysis. In Proceedings of the annual conference of the American society for engineering education, Louisville, KY, June 20–23.

United Nations (2020). *The Sustainable Development Goals Report*. United Nations, New York, NY, USA. ISBN 978-92-1-101425-9. https://sdgs.un.org/sites/default/files/2020-09/The-Sustainable-Development-Goals-Report-2020.pdf

Widmann, J., & Vanasupa, L. (2008). Work in progress – attaining and measuring global competency for engineering graduates. In Paper presented at the 38th ASEE/IEEE frontiers in education conference, Saratoga Springs, NY.

Yu, H. (2012). A study of engineering Students' intercultural competence and its implications for teaching. *IEEE Transactions On Professional Communication*, *55*(2), 185–201. https://doi.org/10.1109/TPC.2012.2186657

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