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International Scientific Research Experiences: Developing Global Citizens and Nurturing Engineers and Scientists of the Future

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Abstract

Undergraduate research experiences are known to increase student interest in research and inspire women and racial minority students to seek science, engineering and technology degrees, putting them on the path toward higher education. It has been suggested that engineering experiences or research projects in international locations, where students are exposed to environmental and sustainability issues connected to social welfare, may compel students to seek advanced higher education opportunities in their later professional paths. In this study, we evaluated the impact of linking authentic research experiences to community development and sanitation rights in an international location. It was hypothesized that the international context of the research experiences would provide students with a global perspective of water reuse challenges and promote increased interest in pursuing an advanced degree in engineering. Through the Sustainable Sanitation International Research Experiences for Students (IRES) Program, US students conducting research in Durban, South Africa in 2015-2017 were tasked with leading 6-8-week long research projects, in collaboration with partners at the University of KwaZulu Natal. Once in the US, students were given opportunities to prepare papers and presentations for regional and international scientific conferences and to conduct K-12 outreach activities. All participants were from groups underrepresented in science and engineering. Data collection included pre- and post-program surveys and post experience interviews. Surveys evaluated research skills, research self-efficacy, and interest in pursuing an advanced degree in engineering (e.g., self-reported research confidence gained through the IRES program was observed to increase over time and was statistically different from the comparison group, $p = 0.038$). Our qualitative results indicate that the awareness of culture, societal needs, and engineering challenges faced in Durban had a positive effect on students' perceptions of how their professional work can have a global impact. The benefits gained from the international research experience have important implications for the environmental engineering education field. These experiences can introduce greater research self-efficacy, foster an interest in engineering field research, inspire students from underrepresented groups, and engage all participants in global issues and impacts.

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Introduction

Globalization promotes collaboration and integration of worldwide efforts, which are aided by technology development and transfer among nations. Globalization has also resulted in new challenges that 21st century professionals must be prepared to face. For example, due to the Earth's temperature and pressure atmospheric changes, the air pollution produced in a country with limited air quality regulations can affect other countries in opposite sides of the world, thus 21st century professionals need to consider the impacts on their work beyond the region or country in which they live. Researchers argue that current engineering education should prepare students to address globalization needs (Downey et al., 2006; Nair, Patil, & Mertova, 2009). To address these globalization needs, the education and training of future engineers should include examination of international issues, collaboration with scholars who take a different approach to problem solving (Downey, et al, 2006) and promotion of environmental education and responsibility concepts (Ananiadou & Claro, 2009) among other skills.

Environmental engineering education is well positioned to provide students with opportunities to take a global approach to environmental problems. Study abroad experiences are known to provide cultural immersion that exposes students to different social situations, and when related to the students' academic program, these experiences provide technical diversity, or different ways to handle professional situations, that otherwise would not be experienced in the classroom or home institution (Downey et al., 2006; Lucena et al., 2008). International research and study abroad experiences result in the development of the individual's global engagement as well as career choices and technical knowledge (Page et al., 2009). Coupling the international academic experience with undergraduate research has become common practice to enhance undergraduate engineering education (Hunter et al., 2006; Laursen et al., 2010).

Many studies document the effectiveness of engineering education and research programs for improving students' self-efficacy (Adedokun, Bessenbacher, Parker, Kirkham, & Burgess, 2013; Marra, Rodgers, Shen, & Bogue, 2009), research confidence (Casad, Chang, & Pribbenow, 2016), team work and leadership skills (Carter, Ro, Alcott, & Lattuca, 2016; Marin-Garcia & Lloret, 2008), and intentions to pursue higher education and careers in engineering (Soldner, Rowan-Kenyon, Inkelas, Garvey, & Robbins, 2012). However, most research on the effectiveness of undergraduate engineering research programs examines universities within the US. There is still much to learn about how undergraduate research experiences in international settings enhance academic self-efficacy, research skills, and global perspectives. The present study sought to test previous findings from US-based research on the effectiveness of undergraduate engineering research programs to improve self-efficacy, team work and leadership skills, and intentions to pursue higher education and careers in engineering. However, this study expands previous research to examine how *international* research experiences impact students' cultural competence and understanding of how engineering applies to global international issues. Further, this study examines whether such experiences encourage students to pursue international environmental research in their professional careers.

Through a three-year International Research Experience for Students (IRES) Program supported by the National Science Foundation and supervised by engineering faculty from southern California and South Africa, undergraduate students in civil, environmental, and chemical engineering from two US institutions were selected to conduct short research projects in Durban, South Africa, focused on various aspects of sanitation, wastewater treatment for agricultural water reuse, and resource recovery. The IRES Program paired US students with faculty and undergraduate students at a university in Durban, South Africa, to conduct 6-8-week long research projects at a field site treating wastewater from a community of ~80 homes. South Africa was chosen for this study because it is a developing country and, as such, has a striking contrast to the US in terms of water and sanitation infrastructure, especially in rural and urban areas where services are scarce. In this setting, South African scientists and engineers are making great headway employing decentralized systems that treat wastewater at low cost, with minimum maintenance, and to a level that is suitable for agricultural applications. The partnership provided exposure of US students to technologies that are not commercially available in the US and infrastructure settings that also typically would not be encountered in their home country.

There were three cohorts of students who participated in the IRES Program between 2015 and 2017, each was supervised by scientists and engineers at the South African university and had opportunities to travel within the country. The IRES participants completed questionnaires before and after their experience to evaluate the impact of the program on competencies such as academic self-efficacy, research skills, research confidence, teamwork, and education and career intentions, and to determine the positive and negative aspects of their cultural experiences.

This paper describes the benefits gained from the international research experience and how the benefits connect to the training of environmental engineering students. It was hypothesized that the international research experience would increase students' (1a) academic self-efficacy, (1b) research skills, (1c) research confidence, (1d) including confidence in leading and working with a team, and (1e) education and (1f) career intentions to pursue engineering. In addition, it was hypothesized that the research experience would provide students with (2a) greater cultural awareness, (2b) global perspectives of water reuse challenges, and (2c) promote increased interest in pursuing an engineering career that can have a global impact.

Methodology

(1)Participants

Between 2015 and 2017, a total of 14 students participated in the research experience. All participants were recruited from two public, Hispanic Serving comprehensive state universities in southern California. Participants included 10 women and 4 men from European (n = 6), Latin (n = 5), Asian (n = 2), and African American (n = 1) ethnic and racial groups. All students identified with a group underrepresented in engineering.

(2)Design and Procedure

To evaluate the effectiveness of the IRES program, the researchers used a pre-test post-test design. All participants completed a 30-minute online pre-program questionnaire that assessed baseline values of the variables of interest including academic self-efficacy, research skills, research confidence, confidence with working in a team, and education and career intentions. After participating in the 6-8-week international research experience, participants completed a 30-minute online post-program questionnaire that assessed the same variables. Finally, participants completed a 45-minute phone interview in which they elaborated on their experiences in the program.

Summer international research experience. Before departing to Durban, South Africa, students attended a three-day orientation in which they were introduced to research techniques, project goals, teamwork dynamics, and cultural sensitivity topics. The first week in Durban included trips to local shopping centers and attractions and visits to the university labs and field research site. Students received training in lab safety, analytic techniques, and field sampling protocols. Under the mentorship of the South African collaborators, the students were assigned to individual projects and were trained to collect and analyze data. All the projects were related to water reuse production in a decentralized wastewater treatment system (DEWATS) at Newlands-Mashu. Students received in-depth training on traditional environmental engineering laboratory techniques, such as chemical oxygen demand, nutrient, and solids measurements, and learned new techniques, such as scanning electron microscopy, metals analysis with aqua regia digestion, duckweed propagation and harvesting, biomethane potential measurement, and flow monitoring with in-situ fluorescence and fluorescein tracer release. Students in the last two IRES cohorts, 2016 and 2017, were partnered with five South African undergraduate and graduate students, who also led independent and parallel projects on different aspects of the DEWATS. Some students in the 2017 IRES cohort also had the opportunity to visit and collaborate with faculty at a second South African university. Students and US faculty maintained regular communication through Skype conversations, email exchanges, and texts on WhatsApp to discuss research progress. At the end of the experience, the US students delivered PowerPoint presentations of their work to an audience of South African students and faculty, and their work was disseminated at the Southern California Conference for Undergraduate Research (SCCUR), in the regional American Water Works Association, California Water Reuse, and the national conferences of the Association of Environmental Engineers and Science Professors, the American Chemical Society Annual Spring Meeting, and at the international Dresden Nexus Conference in Germany .

(3)Measures

The pre- and post-questionnaires included the following quantitative measures.

Academic self-efficacy. An 8-item measure (Chemers et al., 2001) assessing students' beliefs regarding their ability to successfully achieve their academic goals was rated on a scale from 1 (*Very Untrue*) to 6 (*Very True*). Items included statements such as, "I know how to study to perform well on tests" and "I usually do very well at school and at academic tasks." The scale had adequate internal consistency (Time 1 or T1 Cronbach's $\alpha = .70$, Time 2 or T2 $\alpha = .94$). Items were averaged so that higher scores indicated higher levels of academic self-efficacy.

Research skills. The 23-item measure (based on Bell et al., 2003) assessed students' skills and abilities in conducting research with ratings from 1 (*Poor*) to 5 (*Excellent*). Sample items included statements such as, "Ask pertinent and insightful questions about complex issues" and "Employ a range of intellectual tools." Internal consistency was acceptable (T1 $\alpha = .97$, T2 $\alpha =$

.96). Items were averaged so that higher scores indicated greater levels of skills and abilities in conducting research.

Research confidence. The 22-item measure (Seymour et al., 2004) assessed students' confidence in conducting research at every stage of the research process with a rating scale from 1 (*Not at all Confident*) to 5 (*Absolutely Confident*). All statements begin with the phrase "I am confident that I can…" followed by several skills such as "use engineering skills (tools, instruments, or techniques)" and "interpret the results of a study." The scale had acceptable internal consistency at both Time 1 (pre-questionnaire, T1 $\alpha = .97$) and Time 2 (post-questionnaire, T2 $\alpha = .93$). Items were averaged so that higher scores indicated higher levels of research confidence.

Confidence with working in a team. A 13-item measure (Lopatto, 2007) assessing confidence with working with teams was rated from 1 (*Strongly Disagree*) to 6 (*Strongly Agree*). Items included statements such as, "I know how to cooperate effectively as a member of a team" and "I find it easy to follow instructions or take orders from others." Internal consistency was acceptable at both time points (T1 $\alpha = .715$, T2 $\alpha = .91$). Items were averaged so that higher scores indicated greater confidence in abilities to work in teams.

Education intentions. Three questions (Estrada et al., 2011) assessed participants' education plans in engineering. Questions were answered on a scale from 1 (*Very unlikely*) to 6 (*Very likely*) indicating students' plans to attend an MS program in engineering, a PhD program, and to gain experience working in an engineering lab. Items were averaged such that higher scores represented greater intentions to pursue additional education and were analyzed individually.

Career intentions. A 7-item measure (Estrada et al., 2011; Schultz & Estrada, 2010) evaluated students' career intentions in the field of engineering with ratings from 1 (*Strongly Disagree*) to 6 (*Strongly Agree*). Items included statements such as, "I intend to work in a job related to engineering" and "I will work as hard as necessary to achieve a career in engineering." The scale had acceptable internal consistency (T1 $\alpha = .93$). After removing "I intend to work in job related to engineering" internal reliability was acceptable at T2 ($\alpha = .73$). Items were averaged so that higher scores indicated greater intentions to work in the field of engineering.

Results

Consistent with data analytic techniques in the social sciences, the Likert-type data were treated as interval level data. Frequency distributions and skewness statistics were examined, and the data were determined to be normally distributed and met the assumptions of inferential statistics. Quantitative data from the pre- and post-questionnaires were examined using repeated measures *t*-tests to observe changes in values from pre- to post. It was hypothesized that the research experience would increase students' (1a) academic self-efficacy, (1b) research skills, (1c) research confidence, (1d) including confidence in leading and working with a team, and (1e) education and (1f) career intentions to pursue engineering. Qualitative data from the post-program interviews were used to supplement quantitative data testing hypothesis 1. It was hypothesized that the research experience would provide students with (2a) greater cultural awareness, (2b) global perspectives of water reuse challenges, and (2c) promote increased interest in pursuing an engineering career that can have a global impact. To test hypotheses 2a-c, qualitative data from the post-program interviews were analyzed using a grounded theory approach to examine recurring themes. Descriptive statistics indicating the percentage of students who mentioned the theme and quotes are provided to support the claims.

(1) Academic Self-Efficacy

Providing some support for hypothesis 1a, there was a non-significant trend of increased academic self-efficacy from pre- to post, $t(12) = 1.462$, $p = .169$. Participants had slightly higher self-efficacy after the program ($M = 5.297$, $SD = .593$) than at baseline ($M = 5.110$, $SD = .670$). Results from the interviews indicated common responses to describing their research experiences included being pushed beyond their comfort zone typical of a classroom setting (69%) and gaining real world research experience (77%).

(2) Research Skills

There was some support for hypothesis 1b. There was a non-significant trend of increased research skills from pre- to post, $t(12) = 1.490$, $p = .162$. Participants had slightly higher self-reported research skills after the program ($M = 3.97$, $SD = .636$) than at baseline ($M = 3.692$, $SD = .738$). An examination of responses to individual items indicated significant improvements in self-reported ability to balance diverse perspectives when deciding whether to act, $t(12) = 2.132$, $p = .054$, identifying limits of research questions, $t(12) = 3.742$, $p = .003$, and understanding the theory and concepts guiding their research projects, $t(12) = 2.856$, $p = .014$ (see Table 1). In the interviews, participants reported acquiring or improving several research skills including managing data (70%; "You know, you have your own data and learning how to correlate and analyze your own data is definitely something I got from this"), time management (46%), creating a poster (54%; "I learned a lot about…creating posters…about how to compile a poster and how…to analyze data"), writing scientific papers (54%), and oral presentations (46%).

Table 1. ***Self-Evaluation of Research Skills: Test of Hypothesis 1b***

How would you rate yourself on the following skills?	M_{pre} (SD)	M_{post} (SD)
Ask pertinent insightful questions about complex issues	3.69 (.947)	3.92 (.862)
Perceive relations and patterns	3.85 (.899)	3.92 (.862)
Recognize conflicting points of view and move beyond to an independent point of view	3.77 (1.013)	3.77 (.832)
Synthesize from different ways of knowing, bodies of knowledge, and tools for learning	3.85 (.689)	4.00 (.226)
Tolerate ambiguity and paradox	3.15 (.899)	3.31 (.947)
Reflect constructively on your experiences and knowledge	4.08 (.760)	4.00 (.707)
Employ a range of intellectual tools	3.85 (.987)	3.92 (.862)
Solve problems and work through situations	3.92 (.862)	4.15 (.222)
Connect in and out of classroom work	4.00 (.913)	4.23 (.599)
Apply theories to practice in the real world	3.77 (.927)	4.00 (.816)

Balance diverse perspectives in deciding whether to act	3.62 (.870)	4.00 (.707)*
Distinguish multiple consequences of your actions	3.92 (.862)	4.08 (.641)
Go beyond facile answers to engage with the complexity of a situation	3.54 (1.05)	3.69 (.947)
Readily identify ambiguities and unanswered questions	3.68 (.266)	3.62 (.213)
Understand the differences among analysis, synthesis, and comparison	3.62 (1.044)	3.92 (.954)
Analyzing data for patterns	3.69 (.947)	4.08 (.760)
Figuring out the next step in a research project	3.62 (.768)	3.69 (.855)
Problem-solving in general	4.08 (.760)	4.23 (.832)
Formulating a research question that could be answered with data	3.38 (.870)	3.69 (1.032)
Identifying limitations of research methods and designs	2.92 (1.115)	4.00 (.913)*
Understanding the theory and concepts guiding my research project	3.23 (1.013)	4.08 (.494)*
Understanding the connections among engineering disciplines	3.69 (1.109)	4.00 (.913)
Understanding the relevance of research to my coursework	4.08 (.760)	4.23 (.832)

Notes. * $p \leq .05$

(3) Research Confidence

Hypothesis 1c was supported by a significant difference in self-reported research confidence from pre- to post, $t(12) = 2.314$, $p = .039$. An examination of responses to individual items indicated marginal to significant improved confidence in using engineering tools, $t(12) = 1.996$, $p = .069$, using engineering language and terminology, $t(12) = 1.806$, $p = .096$, generating a research question, $t(12) = 1.806$, $p = .096$, defending an argument, $t(12) = 1.760$, $p = .104$, explaining their project to people outside their field, $t(12) = 2.739$, $p = .018$, conducting observations in the lab or field, $t(12) = 1.760$, $p = .104$, calibrating instruments, $t(12) = 2.739$, $p = .018$, and working with computers, $t(12) = 2.309$, $p = .04$ (see Table 2).

Table 2. ***Confidence in Research Skills: Test of Hypothesis 1c***

I am confident that I can . . .	M_{pre} ***(SD)***	M_{post} ***(SD)***
Use engineering skills (use of tools, instruments, and/or techniques).	3.77 (1.013)	4.46 (.660)$^{+}$
Use engineering language and terminology.	3.85 (.689)	4.23 (.599)$^{+}$
Generate a research question to answer.	3.77 (.725)	4.15 (.801)$^{+}$

Figure out what data/observations to collect and how to collect them.	3.77 (.599)	4.08 (.954)
Figure out/analyze what data/observations mean.	3.54 (.877)	3.54 (.776)
Interpret the results of the study.	3.54 (1.127)	3.62 (.768)
Use engineering literature and/or reports to guide research.	4.08 (.641)	4.23 (.599)
Relate results and explanations to the work of others.	3.92 (.641)	3.92 (.760)
Integrate and coordinate results from multiple studies to develop theories	3.67 (.778)	4.00 (.853)
Report research results in an oral presentation or written report.	4.00 (.577)	4.31 (.751)
Writing scientific reports or papers.	3.92 (.494)	4.08 (.641)
Making oral presentations.	4.00 (.408)	3.85 (.689)
Defending an argument when asked questions.	3.54 (.776)	3.85 (.555)$^{+}$
Explaining my project to people outside my field.	4.08 (.137)	4.46 (.519)*
Preparing a scientific poster.	3.92 (.862)	4.23 (.725)
Keeping a detailed lab notebook.	4.38 (.650)	4.46 (.660)
Conducting observations in the lab or field.	4.08 (.862)	4.38 (.650)$^{+}$
Using statistics to analyze data.	3.69 (1.109)	3.69 (1.032)
Calibrating instruments needed for measurement.	3.46 (1.266)	4.23 (.832)*
Working with computers.	4.54 (.660)	4.85 (.376)*
Understanding journal articles.	4.08 (.641)	4.15 (.689)
Conducting database or internet searches.	4.23 (.725)	4.31 (.855)

Notes. * $p \leq .05$, $^{+}$ $p \leq .10$

(4) Confidence with Leading and Working in a Team

There was no significant difference in the pre- and post- self-reported ratings of confidence working in a team. However, participants had slightly higher confidence in leading and working in a team after the program (M = 4.871, SD = .432) than at baseline (M = 4.746, SD = .655), providing some support for hypothesis 1d. An examination of responses to individual items indicated marginal to significant increased confidence in ability to influence a team, $t(12)$ = 1.760, p = .104, and training or supervising students and technicians in the laboratory, $t(12)$ = 2.650, p = .021 (see Table 3).

In the interviews, several students reported enjoying the team-based nature of the experience (46%; "It's really fun to work with…a group of people that you work with for five weeks. I feel like you get really close as a team" and "I would say the best part was really the different student groups") and developing professionalism (54%; "…we were able to actively voice our concerns uh listen to those concerns and address them together in very harmoniously. I thought that was incredible impressive on how we were able to do that”). However, students also expressed challenges with working in teams (54%; “I think that there were people that were more difficult to work with just because there were different personalities”).

Table 3. ***Confidence in Leading and Working on a Research Team: Test of Hypothesis 1d***

	M_{pre} *(SD)*	M_{post} *(SD)*
I know how to cooperate effectively as a member of a team	5.31 (.751)	5.46 (.519)
I find it easy to follow instructions or take orders from others	5.31 (.751)	5.46 (.776)
I have high confidence in my ability to function as part of a team	5.46 (.660)	5.54 (.519)
I can provide strong support for other members of any team that I am on	5.46 (.519)	5.62 (.506)
I know how to be a good team member	5.46 (.660)	5.31 (.630)
I know a lot about what it takes to be a good leader	5.08 (.760)	5.08 (.760)
I know what it takes to help a team accomplish its task	5.15 (.689)	5.38 (.506)
I am confident of my ability to influence a team I lead	5.00 (.913)	5.31 (.630)$^{+}$
I know how to encourage good team performance	5.31 (.751)	5.23 (.725)
I am able to encourage other team members to contribute to the task when leading a team	5.17 (.835)	5.00 (.739)
I can train or supervise students and/or technicians in the laboratory	4.31 (1.601)	5.23 (.832)*

Notes. * $p \leq .05$, $^{+}$ $p \leq .10$

(5) Education and Career Intentions in Engineering

Contrary to hypothesis 1e, there was no clear increase in the number of students who planned to pursue MS or PhD programs in engineering. However, there were changes in students’ plans with some students initially planning to pursue an MS or PhD who changed their minds after participating in the program, and others who initially did not plan to pursue an MS or PhD program changing their plans to pursue a higher degree in engineering. There also was variability in students’ plans to pursue education and training in engineering labs after the program (see Table 4).

Consistent with the quantitative findings, the interview data indicated students did not change, but rather solidified their engineering education plans after participating in the IRES program (70%; “It [the program] did not change my plan, but it did help me to like execute my plan… get on top of my goals and my plans”). The program helped students determine what degree to pursue (45%; “I plan on applying for Master’s program, before I wasn’t really sure. I think this experience um, helped me decide. Cause I do, I really do like research and I like um, going to class and learning more so, I’d really like to continue my education”).

Table 4. ***Education Plans in Engineering: Test of Hypothesis 1e***

	PhD_{Pre}	PhD_{Post}	MS_{Pre}	MS_{Post}	Work in Engineering Lab_{Pre}	Work in Engineering Lab_{Post}
Very Unlikely	7.7%	15.4%	0%	7.7%	0%	7.7%
Unlikely	30.8%	30.8%	7.7%	7.7%	0%	7.7%
Somewhat Unlikely	15.4%	0%	0%	0%	7.7%	7.7%
Somewhat Likely	38.5%	30.8%	23.1%	15.4%	23.1%	7.7%
Likely	0%	15.4%	30.8%	23.1%	15.4%	30.8%
Very Likely	7.7%	7.7%	38.5%	46.2%	53.8%	38.5%

There was no significant difference in the pre- and post- ratings of career plans in engineering. However, participants had slightly greater intentions to pursue engineering careers after the program (M = 5.459, SD = .485) than at baseline (M = 5.436, SD = .692), providing some support for hypothesis 1f. An examination of responses to individual items indicated responses were fairly stable from pre- to post-, with the greatest increase, albeit non-significant, in response to "I feel that I am on a definite career path in engineering" (see Table 5). At baseline, the average rating for career plans was 5.436 out of 6 (SD = .692), which was significantly higher than the scale midpoint of 3.5, $t(12)$ = 10.082, p = .001. This finding indicated participants planned to pursue a career in engineering before starting the IRES program. This strong intention to pursue a career in engineering was strengthened after the program (M = 5.459, SD = .485), $t(12)$ = 14.575, p = .001 (see Table 5).

Consistent with the quantitative findings, the interview data indicated students' career intentions did not drastically change, but rather students solidified their engineering career plans after participating in the IRES program (54%; "It [the program] definitely solidified my career plans… not change them. It didn't change any of my plans or goals"). The program helped students focus their interests within engineering (23%; "It [the program] has definitely opened different doors. I'm not really sure if it's dramatically changed anything, but there are a lot of things I definitely want to pursue") and increased their interest in environmental engineering careers (38%; "It definitely made me like open my mind in working with waste water").

Table 5. ***Career Plans in Engineering: Test of Hypothesis 1f***

	M_{pre} (*SD*)	M_{post} (*SD*)
I intend to work in a job related to engineering	5.69 (.480)	5.69 (.630)
I see the next steps in the field of engineering, and I intend to take them	5.54 (.660)	5.38 (.506)
I will work as hard as necessary to achieve a career in engineering	5.54 (.660)	5.54 (.519)
I expect a career in this field will be very satisfying	5.50 (.798)	5.42 (.793)
I feel that I am on a definite career path in engineering	5.15 (1.345)	5.54 (.660)
I definitely want a career for myself in engineering	5.54 (.776)	5.54 (.519)
Engineering is the ideal field of study for my life	5.31 (.947)	5.31 (.630)

(6) Global Perspective

To examine hypothesis 2, students responded to interview questions asking them to describe their cultural experiences in Durban including the most positive and most negative aspects, and whether the cultural experiences changed their views of engineering. In support of hypothesis 2a, responses suggested students had greater cultural awareness including learning a lot about the culture (54%), feeling accepted (31%), noticing cultural differences and similarities (54%), having a meaningful experience (38%), and experiencing enlightenment (46%). Students indicated they wanted to learn more about Zulu culture before coming to Durban (62%) and wanted more time to work with local students (38%). Students also reported their favorite cultural activities were going on tours of a village (46%) and going on a safari (54%). In support of hypothesis 2b, students mentioned greater awareness of global perspective of water reuse challenges such as being inspired by researchers giving back to their community (46%). In support of hypothesis 2c, several students reported greater interest in pursuing engineering careers that can have a global impact (62%). Representative quotes are provided in Table 6.

Table 6. ***Students' Cultural Experiences in Durban: Test of Hypotheses 2a-c***

Statement and Theme	**Percentage**
Hypothesis 2a: Greater Cultural Awareness	
Learning a lot about culture: "Seeing…how much they bonded over…having this meal and cooking it and just having it was, it wasn't an experience that I would have in America. We have like BBQ's and stuff…it's a little bit different and I like that we had this cultural exchange and we got to share with each other different food and they showed us like traditional dances and stuff like that…I felt very honored to witness stuff like that." "…we went there and learned a little bit about their culture and uh how uh they greet somebody or how you're supposed to greet someone when trying to enter a village. And um, and so we went through that experience, we even like wore	54%

some of the traditional clothing that they have, so that was fun. And um...we did a lot of dancing…we would talk to our Zulu friends I guess we would exchange … languages as well."	
Felt accepted: "I don't feel like I was an outsider. Pretty much everyone in their culture accepted us for who we are. And we accepted them for who they are... and we respected their culture... they respected our culture and um it was a great experience."	31%
Cultural differences: "You [Americans] just always move fast. You drive fast, you try not to be late to class, but you over pack your schedule and um it seemed like they just valued life, like doing things not even necessarily work related, but just-just interactions with each other. Um they value those a lot more. Like dinner out there takes three hours. I came back here, and dinner with one of my friends took like 45 minutes and I was thinking, I'm like, why did we rush? What was the rush?" "…sometimes it was strange, and other times it was really cool. I just liked to observe and see how people at in certain situations, what they would say. I really liked the accents too."	54%
Meaningful experience: "My cultural experience was…a very good one...I feel like I got to interact with different people and…talk to them and hang out with them, it was…very fun…I guess I got to reflect a lot on just being an American student as well."	38%
Enlightening: "I mean I knew that there were people ...in the world who came … from very different circumstances then we do in America. … we don't have the kinds of problems that they have in South Africa, and some of the problems we have here, they are not familiar with."	46%
Desire to learn more: "Maybe um teach us the basics of Zulu before going there. That would be very helpful because we had to learn by ourselves…And maybe … teach us the basics of the culture…like what we can do and what we can't do so that we don't offend them."	62%
Desire for more time working with local students: "Definitely working with the students from the university, maybe even working with them more. Cause that was a big reason why we got to see more of the, the cultural side rather than the touristy side of Durban,"	38%
Enjoyed village tour: "I think it was the trip to the Zulu village. Um…yeah just during the tour, they dressed us up in their national costumes and then they made us dance like their traditional dance and then we learned about their language...I thought that was really unique and fun."	62%
Enjoyed safari: "[It was] like a game drive…like three hours north of Durban it was cool we all cuddled animals and we stayed overnight and then the next morning we walked to…breakfast and just like run into a herd of giraffe."	54%
Hypothesis 2b: Global perspective of water reuse challenges	
Future of engineering: "I'm like much more open minded about going into that field. And also I feel like, um that's a huge direction where environmental engineering is going just because of water reuse and sustainability, and that kind of thing."	55%

Research was inspiring: "The research was really, really cool. I met some people with umm quite a lot of ambition, PhD students and Masters students that wanted to keep working on things so that they could help their homes and their communities uh that was very inspiring."	46%
Understand universal impact of engineering: "I understand how a de-centralized waste water treatment plant works now but going in I was like I know what it is but I don't really understand how it works. And then after spending a couple weeks on the site I'm like okay I understand now, I understand how all these different aspects of it are important."	36%
Hypothesis 2c: Increased interest in pursuing an engineering career with global impact	
"It has changed how I view the field of engineering…I didn't think an engineer would need to know so—such a wide range of other disciplines." "I see its application, it has changed my view… I see that engineering is a very diversified field."	62%
Understand universal impact of engineering: "I feel like it really integrates a lot of things um, not just what we learned in the classroom and in terms of applying but really seeing how that affects different fields. The program you know was very interdisciplinary in the sense that you got to see how your project affects real people or how it's connected to an existing community and how your data is taken seriously. And um. And you're really I guess a part of making a difference."	36%
Work internationally: "I think it would be cool to go to another developing nation and-and work on these decentralized systems… Yeah I had already considered working um in another country, but in Germany in particular, but after doing this, yeah no I'm more inclined to go to developing nations and do that."	27%

Notes. Percentages reflect the number of students who made comments fitting in the theme.

Discussion

Descriptively, all hypotheses were supported indicating that the IRES program was successful in improving students' academic self-efficacy, research skills, research confidence, confidence in leading and working with a team, as well as education and career intentions to pursue engineering. However, because the program provides in-depth, international environmentally-focused research training experiences for a select group of students, the small sample size negatively impacts the statistical power, making detecting differences more challenging. Further, students were selected into the IRES program on a competitive basis, which created a biased sample of students who are already high achieving and have strong motivation to pursue advanced engineering education and careers. Despite these limitations, the strongest inferential claims are made regarding hypotheses 1b and 1c (improvements in research skills and confidence). All data sources, including quantitative survey data, qualitative interview data, and research products (e.g., research papers and presentations) indicate students improved their research skills participating in the IRES program. The skills most directly impacted include ability to consider diverse perspectives in making research decisions, identifying limitations of research methods and designs, and understanding the theory and concepts guiding the research projects (skills nurtured while working with the research group composed of scientists from different parts of the world).

Similar to prior US-based research, students also reported more confidence in their research skills (Carter et al., 2016; Casad et al., 2016; Marin-Garcia & Lloret, 2008) such as using engineering skills, using engineering language and terminology, generating research questions, defending research arguments, explaining research to outsiders, conducting lab and field observations, and calibrating instruments. However, a new contribution of this work is students reporting confidence in working with computers and transferring engineering practices/systems learned in South Africa into the US context. For example, students reported learning that some of the water sanitization issues prevalent in South Africa are ongoing issues in some low-income and rural communities in the US. Students felt more empowered to use their skills in wastewater sanitation within their home communities.

A great outcome of the program is the students' gains on the ability of being able to train or supervise other students; the result could be attributed to the experience of being responsible to plan and carry-on their own research project (including learning how to operate the equipment to collect and analyze samples) and for the coordination and training of other students that provided support on different occasions. In addition, the environmental research projects were carried out in an unfamiliar environment where students where challenged by the resources available (limited availability to instruments, research spaces were shared, limiting access to the experimental site, limited supplies to conduct experiments, constraints set by different researchers and the project motivations), the need to communicate with others, and the required advanced planning to achieve their research goals. Such academic and learning experiences could not have been provided in US (Downey et al., 2006; Lucena et al., 2008), where the research experiences often have someone other than the students acting as responsible party to ensure that equipment is in working or calibrated and that there are enough supplies and time to run experiments and achieve expected results. By contrast, the program provided a complex learning environment where students worked with a German non-governmental group, the local Durban municipality and academic partners; they were asked to keep in mind the needs of all the partners when developing their research projects. This learning experience provided the opportunity of incorporating different points of view when developing or revising research plans. For example, students reported increased abilities in balancing diverse perspectives in deciding whether to act.

Interestingly, in the post evaluation the score for oral presentations score showed a negative trend, though not statistically significant. While this can be perceived as something negative, it could be the result of the students' experience of presenting their research results to an international and diverse group of individuals at UKZN with different notions and standards of communication. Thus, the oral presentation experience may have challenged students' interpersonal skills at first but ultimately may have resulted in an overall improvement of their skills overall after returning to the US to make presentations in front of peers or coworkers. Unfortunately, this study did not include the post IRES experience evaluation of the communication skills. Also, as undergraduate students learn more technical content and are exposed to graduate students, scientist and professionals, they become more aware of the skills they have yet to develop and are better able to self-evaluate their skill sets.

In addition to improving students' research skills and confidence, the IRES program was effective in developing students' global perspectives regarding cultural differences, water reuse, resource recovery, and sanitation challenges in an international setting, and the impact environmental engineers and scientists can make. Qualitative data indicate that all student participants reported positive cultural experiences in Durban, which expanded their thinking about global water reuse issues and how engineering can be used to solve social problems. Many students indicated a new or renewed intention to pursue water reuse and sustainable practices as the focus of the future careers in environmental engineering. The IRES program exposed the participants to a situation where they had to work with people with a wide variety of disciplines (chemists, environmental engineers, managers, administrative assistants, agronomists and agricultural scientist, engineers, laboratory technicians, PhD and MS students) and this situation allowed students to experience a multidisciplinary work setting and the global impact of environmental engineering. The majority of students indicated that they learned about the engineers' need to communicate with professionals from other disciplines, and they noticed the diversity of the engineering field. In addition, nearly half of the students reported that it was enlightening to learn that South Africa and the US share similar environmental issues, but recognized differences in the magnitude of the issues in the two countries. Besides the cultural differences, the IRES students felt accepted, enjoyed the cultural learning experience, and would have loved to have a longer experience.

Conclusion

The results of this research reflect the impact of an international environmental research experience to foster greater research self-efficacy, developing an interest in engineering research, inspiring students from underrepresented groups, and engaging all participants in global issues and in multidisciplinary collaboration. The evaluation results of the international research experience on sustainable water reuse technologies in South Africa reflected generally positive impacts on students' confidence as engineers and researchers. We have some evidence to conclude that international research experiences provide benefits that are similar to domestic research experiences, including increased academic self-efficacy, improved research skills, greater research confidence, more confidence in leading and working with a team, and greater intention for education and careers in engineering. In particular, self-reported research confidence gained through the IRES program was observed to increase over time. However, there was no clear increase in the number of students who planned to pursue MS or PhD programs in engineering, likely due to the already high degree of interest in graduate education displayed by the students who were recruited into the program.

Our qualitative results further indicate that the awareness of culture, societal needs, and engineering challenges faced in South Africa had a positive effect on students' perceptions of how their professional decisions have a global impact. The benefits students gained from the international research experience suggest that adding international research and education experiences to domestic engineering education programs would enhance those programs. In particular, international research experiences may allow students to develop their cultural competence and global perspectives on how engineering is applied in other cultural contexts. With respect to environmental engineering, students became more aware of the water reuse and sanitation challenges faced in another country and how science and engineering skills can be used to address these challenges.

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