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Board 325: International Interdisciplinary Undergraduate Research Program on Big Data in Energy and Related Infrastructure: Challenges and Lessons Learned from the COVID-19 Pandemic and University Policies and Practices

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Abstract

Engineering workplaces are becoming globalized because of the growth of the international economy and improvements in information technology. Engineering programs at three U.S. institutions have collaborated as part of the National Science Foundation's International Experience for Students (IRES) Site Track-1 project to develop a program to improve the global competencies of undergraduate engineering students through a 6-week summer international research training program in collaboration with Universiti Teknologi PETRONAS (UTP), Malaysia focusing on applications of data science and artificial intelligence to solve energy and related infrastructure problems. This paper presents a case study of a collaborative IRES program focusing on implementation challenges stemming from the pandemic and university policies and practices. The COVID-19 pandemic has transformed/disrupted university and workplace activities. This program is no exception, with the first cohort in 2021 having to opt for virtual training. All the student participants saw these benefits, independent of gender, diversity, academic rank, or the nature of their home institutions. In 2022, as the COVID-19 pandemic subsided, the program decided to go for in-person training at UTP as originally intended. Significantly different administrative policies and practices among the partner institutions led to students from two of the U.S. programs having to undergo virtual training for 2 weeks followed by truncated in-person training at UTP for 4 weeks while students from the other U.S. program had to settle for virtual training for the entire 6 weeks. These policies and practices include an application for a required specific type of visa, which is lengthy and delayed by the COVID-19 pandemic, and a policy by some of the U.S. institutions that students must be accompanied by at least two faculty for the entire training period. The survey results for 2022 are being analyzed and presented and discussed in this paper.

Introduction

Developments and transfers of technology across countries facilitate global collaboration and coordination. Researchers suggest engineering education should equip students to meet the challenges posed by globalization [1-2]. To meet these globalization demands, future engineers' education and training should focus on international challenges, the ability to work with researchers with various perspectives on solving problems, and the promotion of environmental education and responsibility. Global exposures offer networking and skill development opportunities unavailable to students in their home country. Students can get international experience in various ways, such as study abroad programs and foreign internships. International exposure has been demonstrated to increase student graduation and retention rates in engineering schools [3]. Higher education institutions around the world are now focusing on how to create engineers who not only have advanced knowledge but also comprehend how culture can influence the implementation of their engineering designs and plans [4].

There are many new and innovative ways to include international experiences in higher education, thanks to the globalization and technological growth of society. American students

majoring in the arts and social sciences were the original target group for these study-abroad programs [5]. Nowadays, international experience is required in the STEM professions as well. Two main considerations constrain the number of engineering students who go abroad to further their education. Many American students who are majoring in more than one field of study identify financial concerns as the main reason they haven't participated in study abroad programs [6]. In addition to the financial burden, students in STEM fields often have to contend with the time requirements associated with study abroad programs. However, many engineering programs have strict course sequencing requirements that make taking a semester-long study abroad program difficult [6]. International exposure has been demonstrated to increase engineering students' likelihood of completing their degrees. One study abroad program at the University of Missouri boasted a nearly perfect graduation percentage for all of its students who participated in the program [7].

Graduate and undergraduate students who are permanent residents or citizens of the United States are eligible for funding through the National Science Foundation's (NSF) International Research Experiences for Students (IRES) program to participate in international research and related activities. The IRES curriculum can be followed in one of two ways. Graduate and undergraduate students in STEM can participate in a collaborative research environment abroad through the IRES Track I program (IRES Sites). In most cases, the overseas host institution is another research university or a laboratory that can supply expert guidance in the student's chosen IRES fields. The IRES Track II (Advanced Studies Institute) program is a brief (15-21 days) yet intensive course designed specifically for graduate students. This is more narrowly aimed at cutting-edge research, and the engagement of eminent scholars in the relevant field is required to justify the choice of a foreign location.

This paper discusses how international research benefits engineering students. The project evaluation results showing how this experience has improved students' academic self-efficacy, research skills, research confidence, teamwork confidence, education, and engineering career intentions are also presented in the paper. In addition, this study also illustrates how the student’s global experiences, such as cultural awareness, worldwide perspectives, and interest in global engineering careers, have changed as a result of this project. Lastly, the lessons learned from the COVID-19 pandemic and its impact on the project implementation and what changes are being made for the next cohort are also discussed.

Project background

Three public universities in the states of Texas, Nevada, and North Dakota are working together on the IRES project. North Carolina Agricultural and Technical State University (NCAT), University of Nevada–Las Vegas (UNLV), and Texas A&M University (TAMU) are the three colleges that participated. Each of the three schools has a unique focus on energy, from fossil fuels to renewable resources, and all three are in states that are frontrunners in energy production and harvesting. The program ultimately opted to move through with in-person training at UTP in 2022 after the COVID-19 pandemic had subsided. Students in two of the U.S. programs had to complete 4 weeks of virtual training followed by 2 weeks of shortened in-person training at UTP due to significant differences in administrative policies and practices among the partner institutions while students in the other U.S. program had to complete the entire 6 weeks of

training virtually. The host country for the IRES 2022 program was Malaysia. Undergraduate students in civil, industrial, mechanical, petroleum, and computer engineering from three institutions were selected to participate in research projects in UTP, Malaysia, related to various aspects of the usage of machine earning and artificial intelligence.

Three distinct objectives were set for this collaborative IRES project:

- strengthen the interest and research abilities of undergraduates from underprivileged population groups who might not otherwise have access to a global opportunity for professional development;
- prepare students with professional skills to enter a diverse and global workforce in the energy and related infrastructure industry; and
- promote collaboration between faculty and students from Asia (one of the fastest-growing regions in the world) and US universities.

Table 1 illustrates the relationship between project goals and objectives and the proposed strategies to accomplish those objectives.

Table 1: Project goals, objectives, and strategies

Goals and Objectives:	**Strategies**
Goal 1: Strengthen the interest and research abilities of undergraduates from underprivileged population groups who might not otherwise have access to a global opportunity for professional development.	
Objective 1: Recruit *9 undergraduate* students from various engineering majors each year for three years, 3/year each from TAMU, NCAT, and UNLV with about two-thirds from women and underrepresented population groups.	**Strategy 1:** Recruit about two-thirds of participating students *from women and underrepresented minority* group*s from* engineering or related disciplines. Of those two-thirds, recruit about one-third from first-generation students. **Strategy 2:** To create multidisciplinary and diverse teams, priority is given to recruit students from multiple engineering majors from three collaborating institutions.
Goal 2: Prepare students with professional skills to enter a diverse and global workforce in the energy and related infrastructure industry	
Objective 2: Provide participants with a 6-week long *high quality multi-disciplinary international research experience* in real world projects using big data and machine learning projects that are energy related at a reputed international institution in Asia.	**Strategy 3:** Collaborate with faculty from Universiti Teknologi Petronas (*UTP) in* Malaysia (*The IRES Site)*, to provide international research and cultural experience to TAMU/NCAT/UNLV students. **Strategy 4:** Collaborate with the host institution team (UTP mentors) to identify real world multi-disciplinary projects for students on the application of data science in energy and infrastructure from local companies.
Objective 3: Provide training and exposure to these students on global cultures, and international workplaces.	**Strategy 5**: Deliver a seminar on Asian culture and social practices (prior to the IRES site visit in Malaysia), and discuss the influence of social values on the workplace culture. **Strategy 6:** Form a joint project team by including students from the Malaysian University (the host) and the US Universities to provide students with a multi-cultural and international team experience.
Objective 4: Use a *rigorous assessment and tracking process*, and *evaluate the impact* of proposed activities on student outcomes.	**Strategy 7:** Through an external and independent evaluator, evaluate the impact of the project by employing a mixed methods research approach consisting of both validated

	instruments for quantitative study, and open-ended structured interviews for the students' experiences.
Goal 3: Foster collaboration between the faculty and students from Asian (one of the fastest growing regions in the world) and American Universities.	
	Strategy 8: Jointly advise the student teams and work on a journal manuscript based on the industrial research project with the objective to develop future collaborative research proposals.

Application and selection process

The participants were selected from TAMU, NCAT, and UNLV. Although applications received from relevant engineering majors were considered desirable, those from other STEM disciplines with a close relationship to big data were also reviewed. The NSF's application submission and management system were kept on a dedicated website (https://www.nsfetap.org/award/103/opportunity/105). Students needed to meet the following requirements to be considered: (a) have an interest in conducting applied research; (b) be majoring in engineering, engineering technology, statistics, or a closely related field; (c) be junior or senior in the upcoming Fall semester/quarter; (d) have a cumulative GPA of 3.0 or higher (on a scale from 4.0); and (f) be citizens or permanent residents of the United States. Principal investigators from Texas A&M University, North Carolina Agricultural and Technical State University, and the University of Nevada, Las Vegas, made up the selection panel. Research experience, grades, familiarity with statistics and data analytics, letters of recommendation, and a well-written personal statement all played a role in the final decision. Figure 1 displays the demographic breakdown of the study's participants by gender, race/ethnicity, and area of study (engineering). This demonstrates that the project's diversity targets were met. For example, as shown in Figure 1, of the nine students selected, 22% were female, 22% were African American, and 33% were Hispanic students. Furthermore, it is important to mention that the program also successfully maintained the multidisciplinary nature of projects (Figure 1).

Research and training activities

This six-week summer research program was supposed to take place in Malaysia so that participants may experience a new culture and setting of the workplace. However, due to a delay in visa approval students could not visit the country for entire six weeks. There were two other major issues: first, some students didn't have their passports ready to apply for the visa on time; and second, due to the university policy at NCAT, the three students from that institute could not travel. They participated in the program virtually. The spirit of the virtual program was preserved through the incorporation of a variety of activities and online seminars. For instance, there were three seminars focusing on research methodology, introduction to data science, and machine learning.

Students were mentored jointly by the UTP (IRES Site) faculty and an American faculty, with UTP faculty being in the lead mentoring role. The faculty mentor was on-site in UTP, and he/she met with each IRES student individually for two weeks to ensure their professional and personal

well-being. At the end of every week, students attended a meeting with the UTP mentor and co-mentor (one of the PIs from TAMU, UNLV, or NCAT) and update on their work progress, plan for the following week including a description of what new goals are set for the coming week, and the fun thing they did in Malaysia during the week/previous weekend. The cultural activities were managed by the Student Mobility Office at UTP. As a part of the cultural activities, the students did Royal Belum Rainforest Tour, Gopeng River Tubing, Gua Tempurung Caving, a visit to Kuala Lumpur, and a local food tour.

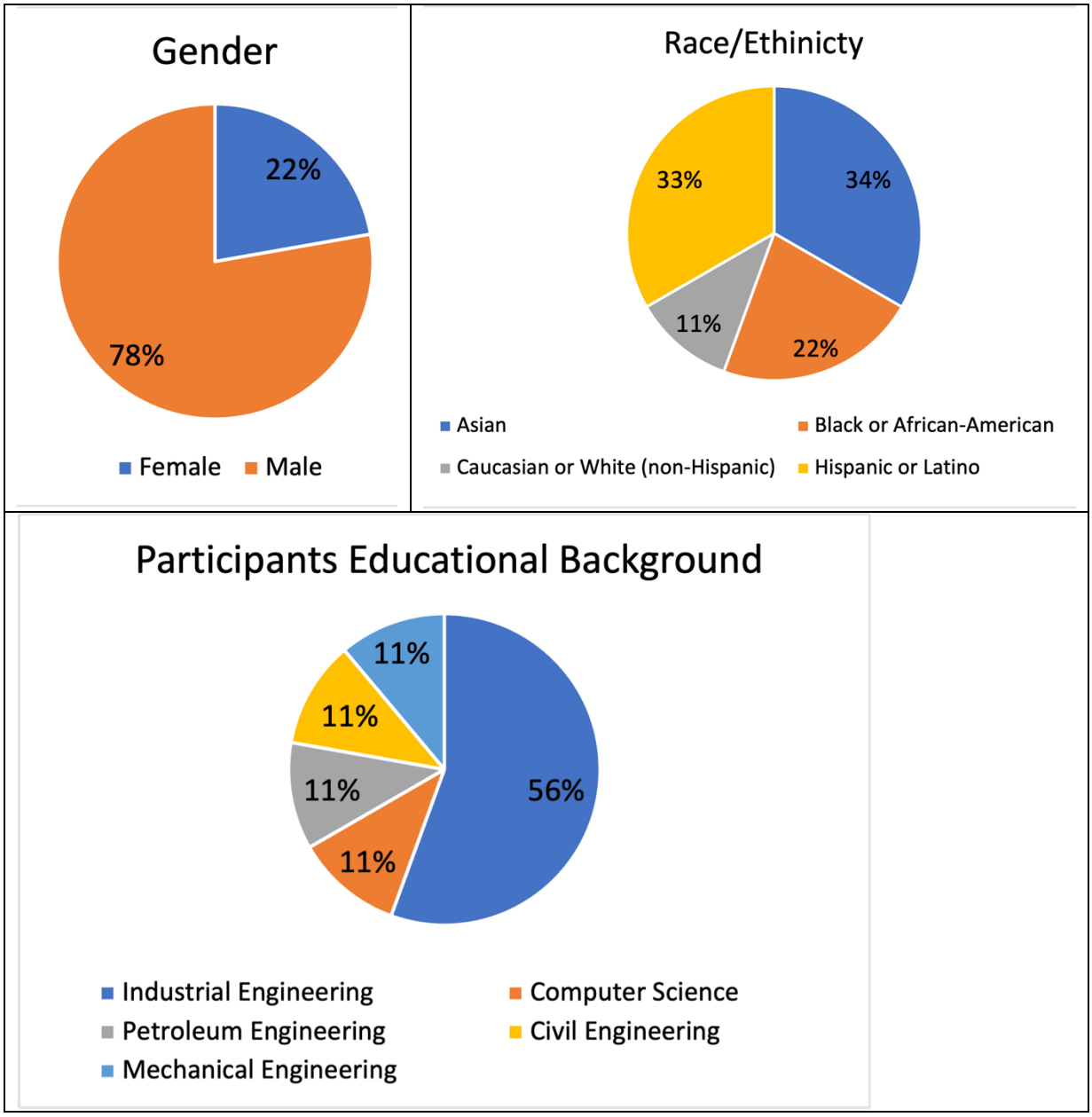

Figure 1: 2022 IRES participants' background/demographic information

Research projects and teams

The students were split into three groups, each of which was led by a faculty mentor from UTP, a faculty co-mentor from one of the collaborating U.S. universities, and a graduate student mentor. No two students were from the same school to ensure diversity. Each student group collaborated with their advisor to determine the goals and outcomes of their project. In 2022, these three projects were selected:

1. *Fire Accident Image Processing and Classification from UAV Using AI for Forest Fire*
   The fundamental goal of the project is to lessen the harm caused by fire accidents by using early fire detection techniques. For this project, forest fire (Tick fire, Los Angeles County, CA) data from an Unmanned Aerial Vehicle (UAV) was collected. Weather conditions data before ignition were collected to teach Artificial Intelligence (AI) to identify fire. Using the YoloV3 algorithm, the segmented fires dataset went through the process of classifying, training, and testing for the final model results.
2. *Predictive Maintenance for Facilities Failure Prediction using Machine Learning*
   Facilities (machine or equipment) failure is one of the most critical aspects to be considered in industries. Failure could create major downtime, halting production, unplanned maintenance costs, and reduced product quality. Therefore, a prediction model that can forecast facility failure is needed to be developed. This study involved an investigation in determining the most appropriate machine-learning algorithm for the developed model. The team was given a set of data from a sensor on oil equipment that had three failures. This data was preprocessed, modified, and standardized before a correlation analysis was performed. Multiple machine learning models were developed and analyzed using Python, Pandas, and Scikit-learn. Among them were simple and multiple linear regression models, gaussian regression, decision trees, and random forests.

3. *Prescriptive Maintenance Model using Deep Learning: A Remaining Useful Life Prediction applied to Turbofan Engine*
   Deep Learning is a type of machine learning, where the model learns from multiple sets of data. The model will recognize patterns across data sets and use information learned from them to make predictions. Deep Learning requires large amounts of data to be accurate enough to make predictions. For this project, sensor data was taken from several engines at specific areas of the engines. This data measured the quality of the given parts over an extended period and compared it with the overall RUL of the engine. This allowed the team to see what parts of the engine have a greater significance in overall RUL. The code used to cluster and analyzed the data was written in Python and MATLAB. The use of Deep Learning and Predictive maintenance will help prevent unexpected damages, saving operators money in maintenance and repair costs.

Program Evaluation and Survey

All three universities used an independent project assessor to externally evaluate the IRES program. The formative and summative evaluations were conducted by using a mix of qualitative and quantitative methods. Students completed a survey prior to- and at the end of this 6-week session to assess its usefulness and satisfaction. The formative evaluation helps determine

whether project goals were met and what hampered their implementation. A summative review assessed this program's impact on student's professional abilities for global employment. The Global Perspective Inventory [20] and Engineering Global Preparedness Index were used to create a survey (e.g., the belief that one can make a difference through engineering problem-solving). The evaluator used a Likert scale to poll students before and after IRES. The survey tool examined research skills and global perspective inventory professional skills.

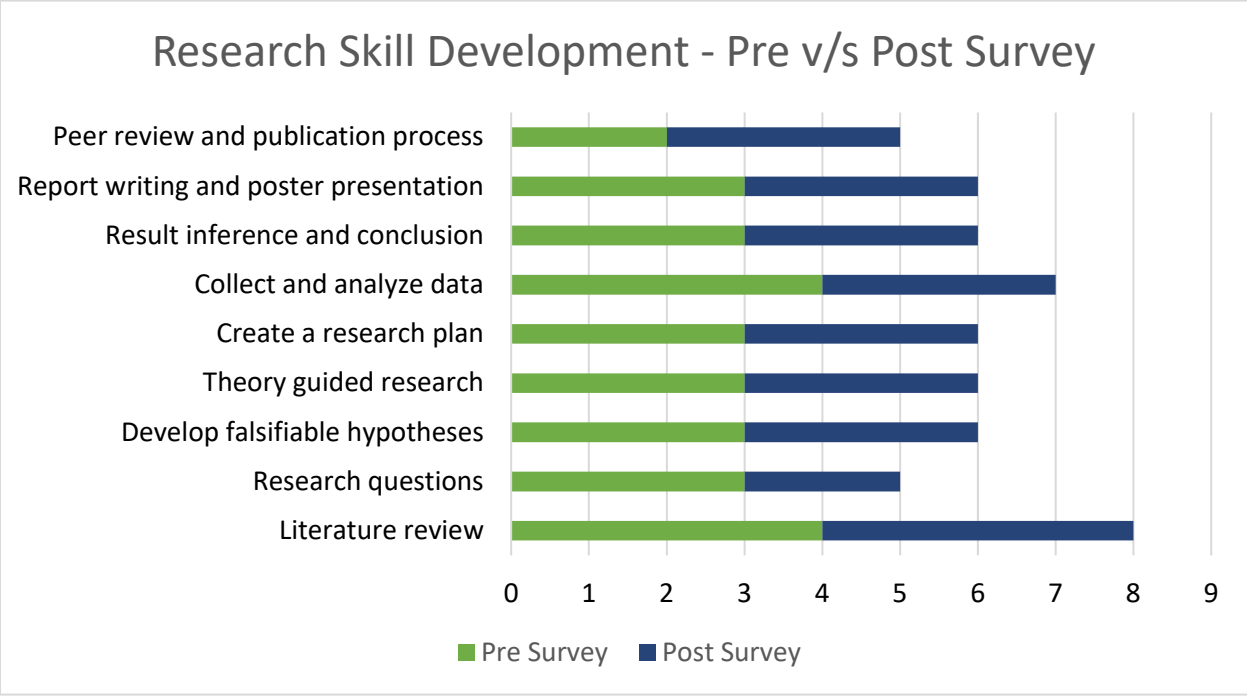

Figure 2: Average research skills score before and after the IRES program

Figure 2 displays research ability survey results both before and after participation in the IRES program. Compared to last year, there was little improvement in research abilities across all 9 criteria from "peer review and publication process" to "literature review" as seen in the bar chart. 0% to 63% (0 to 5 out of 8) of respondents rated their level of ability as good or extensive after the program. This is a notable decrease from 11%-78% (1 to 7 out of 9) good or extensive ratings from before the program. The areas of peer review and publication process showed the highest improvement across the board. Also, the highest-rated skills at the end of the program were the ability to conduct an online search and identify relevant background literature. 63% of respondents rated themselves as good or extensive after the program.

Table 2: Description of questions related to global perspective inventory

Question	Description
A	I take into account different perspectives before drawing conclusions about the world around me.
B	I consider different cultural perspectives when evaluating global problems.
C	I understand how various cultures of this world interact socially.
D	I can discuss cultural differences from an informed perspective.
E	I can explain my own personal values to people who are different from me.
F	I am willing to defend my views when they differ from others.

G	I am accepting of people with different religious and spiritual traditions.
H	I am open to people who strive to live lives very different from my own style.
I	I think of my life in terms of giving back to society.
J	I consciously behave in terms of making a difference.
K	I frequently interact with people from a race/ethnic group different from my own.
L	I frequently interact with people from a country different from my own.

Table 2 outlines the survey questionnaire used both before and after training to assess progress in professional skill development, with a focus on the global perspective inventory. Figure 3 shows the difference in scores on questions testing students' global awareness before and after completing the IRES. Data from both the pre-and post-IRES surveys showed that, on average, students scored higher on the post-IRES survey, indicating greater agreement with the statement supplied in the question.

Figure 3 has a few intriguing observations. First, students' ratings of their ability to argue for their point of view dropped slightly (Question F in Table 2). One possible interpretation is that their typical level of politeness in expressing their opinions has not changed because of this program. Second, students' ratings on interaction with people from different countries also decreased after the program. It may be because the students participating in this year's program already attending institutions with established multiethnic environments.

Students' level of agreement with the global learning skills/beliefs increased from before to after the program: taking into account different perspectives, considering different cultural perspectives when evaluating global problems, understanding how various cultures interact socially, ability to discuss cultural differences, thinking of one's life in terms of giving back to society, and consciously behaving in terms of making a difference. Before the program, 33% to 89% (3 to 8 out of 9) of students agreed or strongly agreed with these items. After the program, 50% to 100% (4 to 8 out of 8) agreed or strongly agreed.

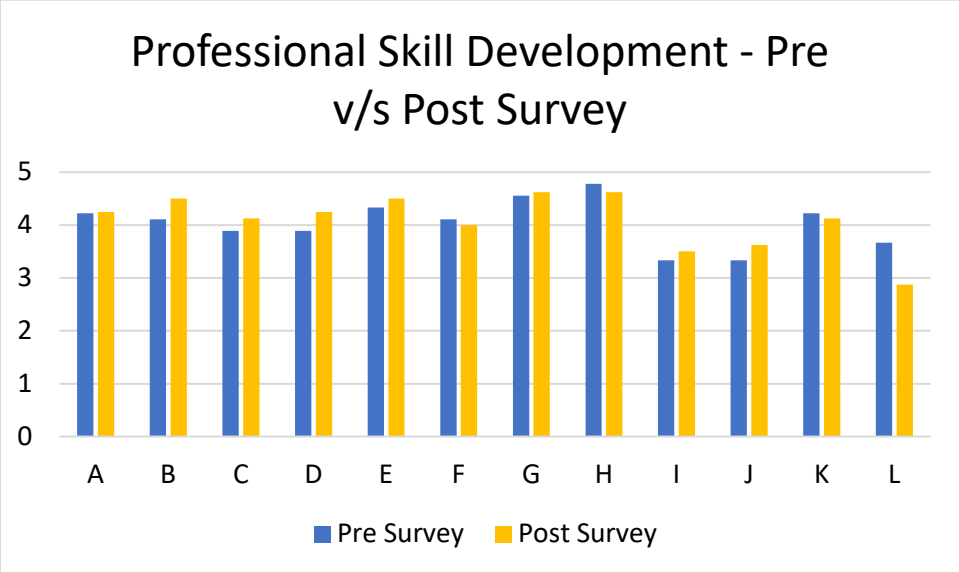

Figure 3: Average professional development score before and after the IRES program.

Challenges and lessons learned

We had a major logistic challenge last year due to the ongoing pandemic situation. For example, it was uncertain whether the students could visit the IRES site in the summer due to ongoing travel restrictions in the host country (Malaysia). This year we started the travel plan as soon as the travel restriction was lifted. However, due to delays in visa approval students could not visit the country for entire six weeks. There were two other major issues: first, some students didn't have their passports ready to apply for the visa on time; and second, due to the university policy at NCAT, the three students from that institute could not travel. They participated in the program virtually. To avoid a similar challenge, we are requiring each participant to have a valid US passport at the time of their interviews for selection. In any case, students must have their passports ready by the end of March so they can apply for Malaysian visas by the first week of April.

Following is a summary of the lessons learned during the 2022 IRES program.

- Students may benefit from a workshop or hands-on experience with research skills, specifically regarding developing testable and realistic research questions, creating a falsifiable hypothesis, and creating a research plan because these were the lowest-rated skills on the post-survey. In the future, we should consider encouraging mentors to provide students with opportunities to develop these skills.
- To address students' concerns, prior to accepting new students, PIs should be aware of the protocols and necessary documentation needed to study abroad. All the necessary documents (e.g., visas) should be completed and processed in enough advance for students to leave when expected.
- To improve students' experiences, participants should be aware of the expectations of the IRES program, including the requirements of the program and a timeline for when they should be completed. Also, a resource about the program should be provided (e.g., a handout of program goals) to the participants.

Conclusions

This article highlighted the impact of the second cohort of students participating in an NSF-funded IRES program on their research and professional development while abroad. Big data in the energy sector and associated infrastructure was the focus of the IRES site. Nine US students, three each from TAMU, UNLV, and NCAT participated in the program. Students worked on one of three interdisciplinary groups, each of which was led by a member of the host institution's faculty and a graduate student, as well as a member of the faculty and a student from one of the other two institutions. Under their guidance, all three groups conducted studies that applied data science and machine learning to problems in the energy sector or a closely related field. The results of the IRES program on students' research skills and their ability to interact effectively with people from different cultural backgrounds were measured using a standardized survey instrument. Participants reported an increase in their average research competency ratings after completing the program, as indicated by the survey findings. Those improvements cut across demographics such as gender, race/ethnicity, socioeconomic status, and school type.

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