

## **Research Experience for Undergraduates: Integrated Optics for Undergraduate Native Americans (IOU-NA)**

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Daniel Lamoreaux is a current doctoral candidate in the University of Arizona's School Psychology program. While working as a graduate assistant for the education office of the Center for Integrated Access Networks, he was directly involved in the coordination and evaluation of the center's summer research programs for Native American students and teachers. His primary interests lie in the education of students with culturally and linguistically diverse backgrounds, and in the effect of built space on school social and academic environments.

## NSF Research Experience for Undergraduates Integrated Optics for Undergraduate Native Americans: Bridging the Gap Between Native Americans and STEM

### Abstract

The National Science Foundation (NSF) funded Research Experience for Undergraduates (REU) program, entitled Integrated Optics for Undergraduate Native Americans (IOU-NA) (#EEC-1359163), is a multidisciplinary REU in the Center for Integrated Access Networks (CIAN), an NSF funded Engineering Research Center (ERC) at the University of Arizona. The IOU-NA supported up to 8 students in a 10-week summer research experience for three summers in labs across the College of Optical Sciences and the College of Science. This program was developed based on theories of student departure and persistence in college, as well as American Indian identity theories and serves as a catalyst for persistence in STEM undergraduate programs and as a recruitment pathway toward graduate studies in STEM. This program provided opportunities for students to incorporate themselves academically and socially into an engaging research project and to make informed decisions about their occupational goals through a series of presentations and workshops with the focus on Native American cultures. This IOU-NA provided Native American undergraduates (n=23), mostly from non-research institutions, an opportunity to engage in meaningful research and build positive academic experiences with peers and student and faculty mentors. Participants were from 10 different tribes: Navajo, Caddo, Comanche, Colorado River, Tohono O'odham, Port Gamble S'Klallam, San Carlos Apache, Blackfoot, and Assiniboine. Fifty two percent were freshmen or sophomores; 35% were female; 48% from community colleges or tribal colleges; 74% were from colleges with limited research/STEM research opportunities; and 48% were first generation college students. The IOU-NA occurred in concert with the Undergraduate Research Opportunities Consortium (UROC) at the University of Arizona, which provided graduate school information, application guidance, and GRE training. Further, participants engaged in professional skills workshops, such as, technical writing, oral communication skills, and presentations about industry options in optical sciences. Participant deliverables included presentation of a research poster, oral presentation of REU research, and an extended research abstract. Since the conclusion of the program, 61% of participants have presented at or attended professional conferences and one student was awarded a patent with his faculty mentor based on his REU research. Ten participants have thus far successfully graduated with their A.S. (3) or B.S. (7) degrees. Of the seven B.S. graduates, five were accepted to graduate school, one is in the process of applying to graduate school, and one is working in a STEM field. Each A.S. graduate is currently pursuing BS STEM degrees at research universities. Outcomes of this REU program support the importance of positive and meaningful academic experiences and relationship-building within the context of culture and identity on persistence in four-year STEM degrees and into STEM graduate programs.

## Introduction

CIAN's Integrated Optics for Undergraduate Native Americans (IOU-NA) Research Experience for Undergraduates (REU), a National Science Foundation funded program, is a proven multidisciplinary program that provides research experiences to undergraduate students who identify as Native American. This program provides unique and quality research opportunities to students who may have minimal alternatives for undergraduate experiences of similar caliber. The primary IOU-NA objective is to expose Native American students with limited research opportunities to top-of-the-line and innovative research environments in optics and photonics, including, but not limited to hydrology, chemistry, biology, environmental sciences, and other sciences. This fulfills the ultimate goal of initiating or developing aspirations in these students to pursue scientific careers and graduate studies in STEM fields. The IOU-NA program ensures students are given opportunities and encouragement to gain knowledge and confidence, learn and apply essential tools necessary in the scientific inquiry process, and receive peer support designed to provide encouragement for pursuing graduate degrees in STEM.

## Overview/Goals

Activities in the IOU-NA were developed based on research on retaining and furthering Native American students in STEM majors, into graduate studies in science and engineering [1] [2]. IOU-NA students gain research experience in labs in the College of Optical Sciences (OSC) and College of Science (COS); participate in Native American focused workshops facilitated by University of Arizona's Native American-serving entities; gain hands-on experience in CIAN's Optics Research Workshop (ORW); attend presentations given by NA STEM graduate students, Sloan Scholars, and Native American STEM faculty; as well as participate in other activities designed to support and encourage graduate school through our partnership with Undergraduate Research Opportunities Consortium (UROC). Students who have successfully completed this program have gained essential scientific knowledge related to their projects, professional development skills that will help them excel as engineers and/or scientists, gain confidence and skills to apply for and succeed in graduate school, and develop relationships with peers and faculty that will open doors for them throughout the remainder of their academic careers and beyond [3].

## Research Motivation

Through CIAN's partnerships with institutions serving the Native American student population, it has become increasingly evident that there is an enormous need to support Native Americans pursuing STEM fields. With only 42% of Native Americans pursuing any form of higher education and only 13% of that number attaining a bachelor's degree or higher, the need for programs to support Native Americans in undergraduate STEM fields is immediate [4]. Native Americans trail behind other URM in STEM education. The Brookings Institute released a report emphasizing the need to fund programs that provide greater equality in educational attainment. The report found that demographic disparities within the STEM workforce can be diminished, boosting the STEM employment and US leadership in technology and innovation by funding initiatives that support these types of programs [2] [5]. Department of Education data reveal

Native Americans and Alaska Natives make up a staggering .4% of total students enrolled in 4-year institutions in the U.S. Further, this population makes up only .1% of total students pursuing graduate studies in the U.S. [6]. The challenges of being a Native American in a STEM major was evident when one of CIAN's 2013 IOU-NA students came to Dr. Huff saying, "I don't fit in here. I want to quit." With encouragement, the student finished and was phenomenal presenting the research. This encounter and scientific research strengthen the theory that other Native American students may face similar challenges unique from other minority groups, which helped to inspire the creation of the IOU-NA REU program [2] [3] [6]. Early hands-on research experiences are a proven method to encourage undergraduate students to pursue careers in STEM, and this is especially true for the Native American population [2]. The IOU-NA REU program is an essential step ensuring these unique students gain the confidence and tools needed to graduate with bachelor's degrees and pursue graduate degrees.

### IOU-NA REU Program Structure

IOU-NA students will join experienced CIAN research teams working on improved fiber optics, waveguide materials, short-pulsed lasers, nanofabrication, silicon photonics, and nonlinear photonics, as well as teams in the COS, specifically in the area of Hydrology and Environmental Sciences. This interdisciplinary approach will provide REU participants with a more rounded research experience. Environmental Sciences is an important field to Native Americans, as the impacts of resource development on Native lands are immense, and continue to have life-saving and life-altering potential for Native Americans living on reservations [7]. The IOU-NA program also prepares students for the challenges of modern engineering and research by providing a series of trainings and workshops that deliver information and strategies for success in STEM careers and education, practice in communicating the application and motivation of their research projects, and encouraging ambition to publish and share research at conferences, while encouraging them to share these developed skill sets within their tribal and urban communities.

Activities and presentations the IOU-NA students participate in include 1) Native Nations Institute: Workshop on Tribal Governance, 2) Laser Radiation Safety Training, 3) Chemical Lab Safety Training, 4) Research Ethics Training, 5) Optics Research Workshop, 6) Sloan Scholar Speaker Series, 7) Research Plan and Lab Notebook Training, 8) Kathryn Kellner Presentation Skill Lecture, 9) Dr. Julius Yellowhair, Sandia National Labs Presentation, 10) Joshua John, Raytheon Presentation, 11) GRE Preparation Course, 12) GRE Tutoring Sessions 13) GRE Final Review, 14) Graduate School Symposium, 15) Don Asher's "Getting into Grad School" Seminar, 16) Performing Research on Reservations Workshop, and 17) Publication Colloquium. The IOU-NA program developed these activities uniquely to mentor and motivate Native American students with the following programmatic objectives in mind [2] [3] [4]: 1) assist in the retention of Native Americans in STEM majors; 2) increase awareness of performing research in tribal communities; 3) promote collegiality among other REU students and faculty and graduate student mentors; 4) increase confidence in effective communication of technical information; 5) develop and/or improve the understanding of the empirical research process; 6) increase competence in working in a research lab; 7) increase awareness of peer-reviewed publication; and 8) improve knowledge of the field of photonics and environmental science. By meeting these additional programmatic objectives, the likelihood of each participant meeting the primary IOU-NA objective of pursuing graduate studies in STEM is increased. Additionally, all

IOU-NA students will participate in the programs' activities as one group, but experience a larger cohort joined by over 100 other REU students across campus through a distinct university program called the Undergraduate Research Opportunities Consortium (UROC). Being part of UROC enriches the REU experience by adding excellent professional development and graduate preparation workshops. Through the combination of research experiences, professional experiences, and the inclusion of cultural aspects, the IOU-NA students experience a unique introduction to the world of academia with a focus in research and higher education.

### IOU-NA REU Participant Results

Over the last three years of the previous IOU-NA, 23 NA students were supported from 10 different tribes, 14 different universities, and many were freshmen and sophomores. All of the participants were underrepresented minorities (35% female). Additionally, 74% of the participants were from institutions with limited research opportunities, and 53% were early career college students. Thus far, only 2 participants did not continue with their college degree programs. One participant suffered from mental health problems and, through the efforts of the staff and PI of this IOU-NA, was able to receive the help needed and placed in the care of his family member in another state. The other participant who left school did so due to family issues back on the reservation. This is not uncommon with Native Americans, who place great value on caring for family. The participant has committed to continue his education when the issues resolve, and we continue to maintain contact with him. Ten participants graduated total, three with their A.S. and seven with their B.S. Of those who graduated with their bachelor's, five have been accepted to graduate school, one is in the process of applying to graduate school, and one has accepted a position in a STEM industry position. All A.S. graduates are enrolled in a university pursuing their BS degree. Already, these REU students' research has advanced their respective fields. Significant examples of these advancements are as follows: 1) A previous IOU-NA participant submitted a patent application based on the REU research with his faculty mentor, which has since been awarded. 2) Another IOU-NA's REU project investigated light pollution on her reservation. She collected and analyzed data on the impact light pollution had in her community. Not only did she present her results at a national conference, she reported her findings directly to the tribal council so they could make informed decisions for their community. This participant also received the Dark Sky Defender award from the International Dark Sky Association for her IOU-NA REU work. 3) Additionally, this year an IOU-NA worked on a project for which the results have immediate and transformative potential. She studied the current and very real-world issue of the Gold King Mine spill on the Navajo Nation. Data from her project is being used to assist in determining the level of contamination and options for clean-up.

### IOU-NA REU Survey Results

The 2014-2016 Integrated Optics for Undergraduate NAs (IOU-NA) REU funded 24 participants to conduct STEM research at the University of Arizona; 10 of these students reported that this experience was their first research experience, and 6 students reported being first generation college students. After the program 19 students completed the post-survey, which asked students to rate the program as well as report on their scientific knowledge, skill confidence, attitudes

toward engineering and their self-efficacy, plans for graduate school and beyond. The pre/post comparison results are described below.

*Participant Perceived Program Strengths and Weaknesses*

Students were asked to report their attitudes regarding potential strengths and weaknesses of the program. These results are represented in Figure A. For instance, students rated their level of agreement with the following statements: my mentor was helpful, I could easily get help when I needed it, the guidance I received from faculty was appropriate, the graduate students in the lab were helpful to me, I felt like a valuable team member, and I understood the real world applications of the research that I was involved in. General attitudes in response to these program statements were highly positive, with all statements receiving positive feedback from 84% or more (16) of respondents (See Figure A). For each item, a large majority either agreed or strongly agreed; the highest rated items which represent strengths of the IOU-NA program included: the guidance I received from faculty was appropriate, I felt like a valuable team member, and I understood the real world applications of the research I was involved in; at least 89% (17) of students agreed with these statements.

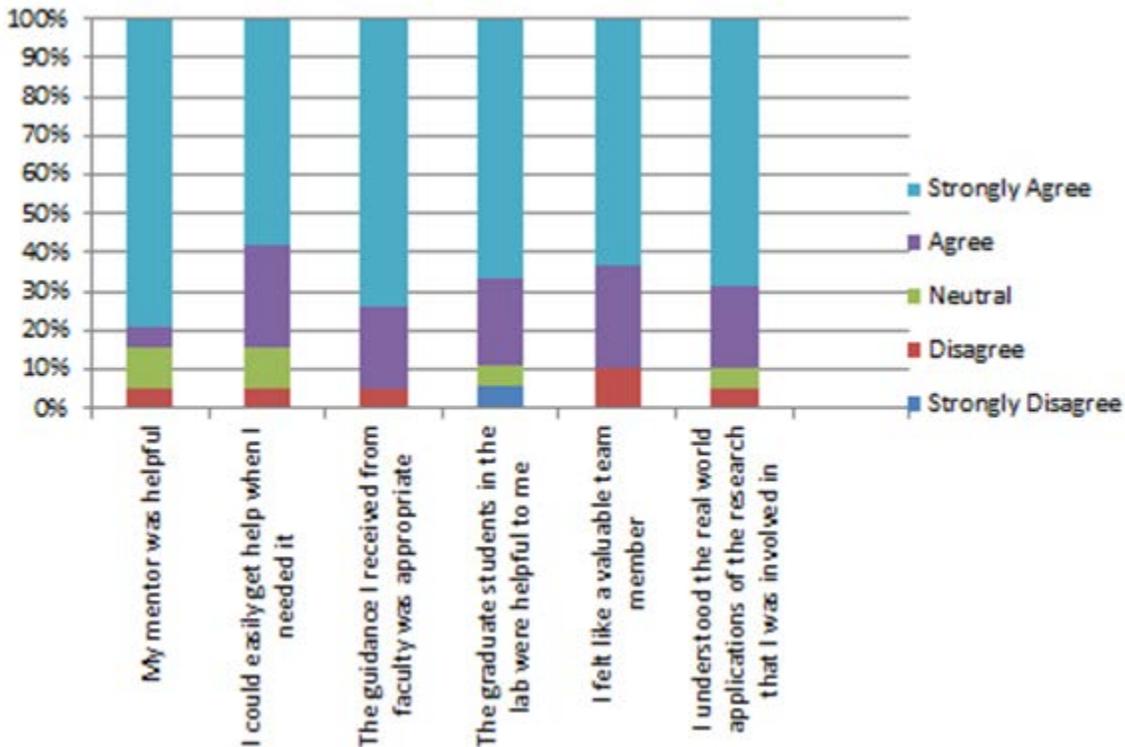


Figure A. Ratings of miscellaneous REU topics

When asked about potential deficiencies in the REU program, there was a focus on clearly defined goals and timelines; 47.1% (8) of the students wanted more assistance regarding their personal direction, classes, and research. Some of the challenges faced by the students involved data analysis, deadlines, needing help and communicating to mentors, learning new research techniques, and working in a new engineering field. To improve the program in the future,

students suggested incorporating more programs and involvement in Native communities, more lab time, and more communication and support from advisors.

Overall, 84.2% (16) of REU participants said that the research internship met their expectations, 84.2% (16) rated the experience as very good or excellent (100% rated the experience as good, very good, or excellent), and 89.5% (17) agreed that the experience has greatly strengthened their graduate applications. Fifty two point six percent (10) indicated they plan on presenting their research at their home institutions. When asked what was most beneficial about their summer research experience, the responses included working with graduate students and faculty, interacting with other Native Americans, conducting research in labs, listening to guest speakers, and attending symposiums on graduate school. These reports demonstrate the many strengths of the program, the few deficiencies, and the students' view of the program.

#### *Participant Perceived Self-Confidence*

Participants were able to demonstrate their scientific knowledge through various research projects. All participants were able to describe the purposes of their research in great detail, using technical language specific to their research fields (optics, hydrology, atmospheric science, materials science). This suggests that a significant, scientific knowledge base was established as a result of their REU. Students were also asked to report on their attitudes regarding their skill confidence in engineering. For instance, students rated their confidence in specific research-related activities, and following the IOU-NA program, confidence improved in many areas (See Figures B and C). Notably, the greatest skill confidence after the IOU-NA program included: conducting literature searches (100%, 19), keeping a lab notebook (84.2%, 16), communicating ideas to team members (84.2%, 16), and preparing a scientific presentation (84.2%, 16). Upon completing the REU program, student ratings indicated the main skills that still show potential for improvement, which involved interpreting research results (68.4%, 13), delivering a scientific presentation (68.4%, 13), and writing a paper suitable for publication (57.9%, 11). However, the several professional development skills that improved as a result of this program will help these students excel as engineers and/or scientists.

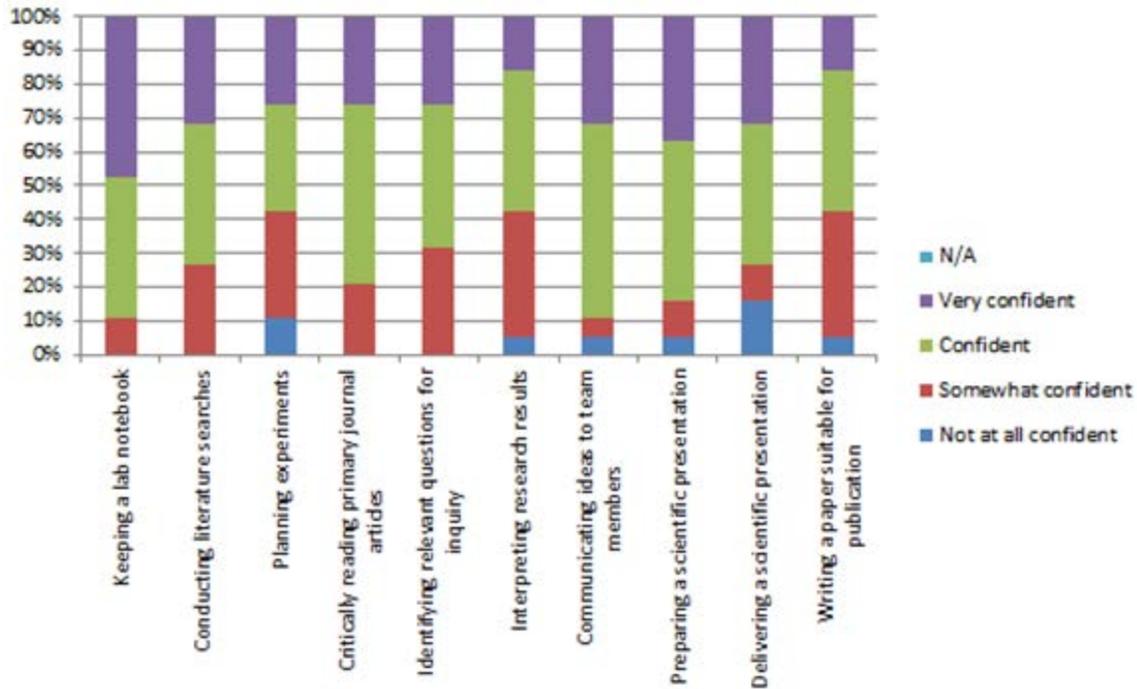


Figure B. Pre-IOUNA confidence

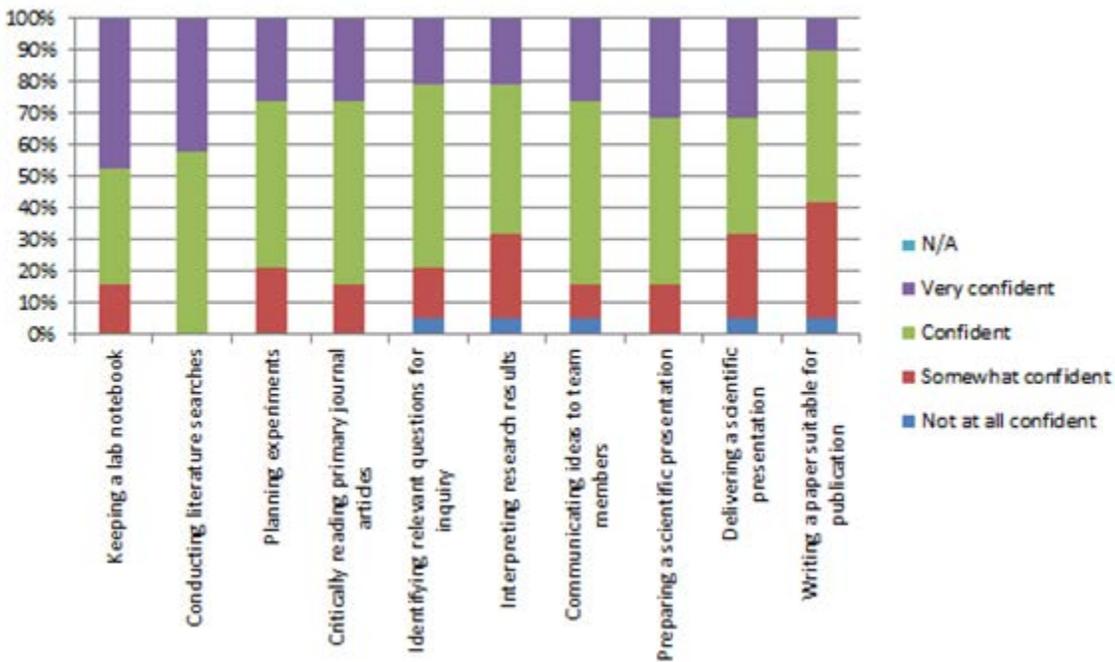


Figure C. Post-IOUNA confidence

### *Participant Perceived Attitudes*

Students rated their attitudes towards engineering and their self-efficacy in engineering as well. For instance, students were asked to rate their agreement regarding the following statements: I think of myself as an engineer, I am confident in my ability to work in a research lab, I am going

to pursue graduate studies in engineering research, I am going to pursue a career in STEM, and I am confident about my ability to access experts in the engineering field. Attitudes regarding most of the above statements improved after students completed their summer program (See Figures D and E). After the REU, 73.7% (14) agreed that they think of themselves as engineers, compared to only 47.4% (9) prior to the program. The most important improvement was about students' desire to attend graduate school; before the program, only 52.6% (10) said they are going to pursue graduate studies, whereas after the REU 89.5% (17) indicated they will pursue graduate studies. Another improvement was that after the REU, 84.2% (16) of the IOU-NA participants said they plan on pursuing a career in STEM, as compared to 52.6% (10) before the program.

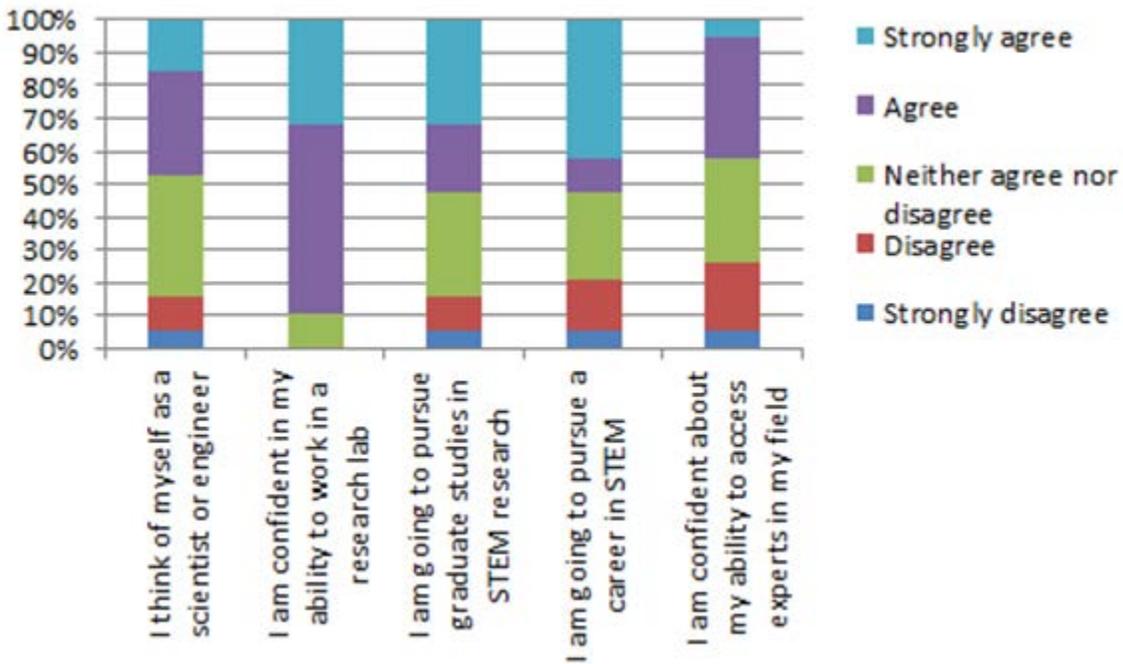


Figure D. Pre-REU agreement ratings

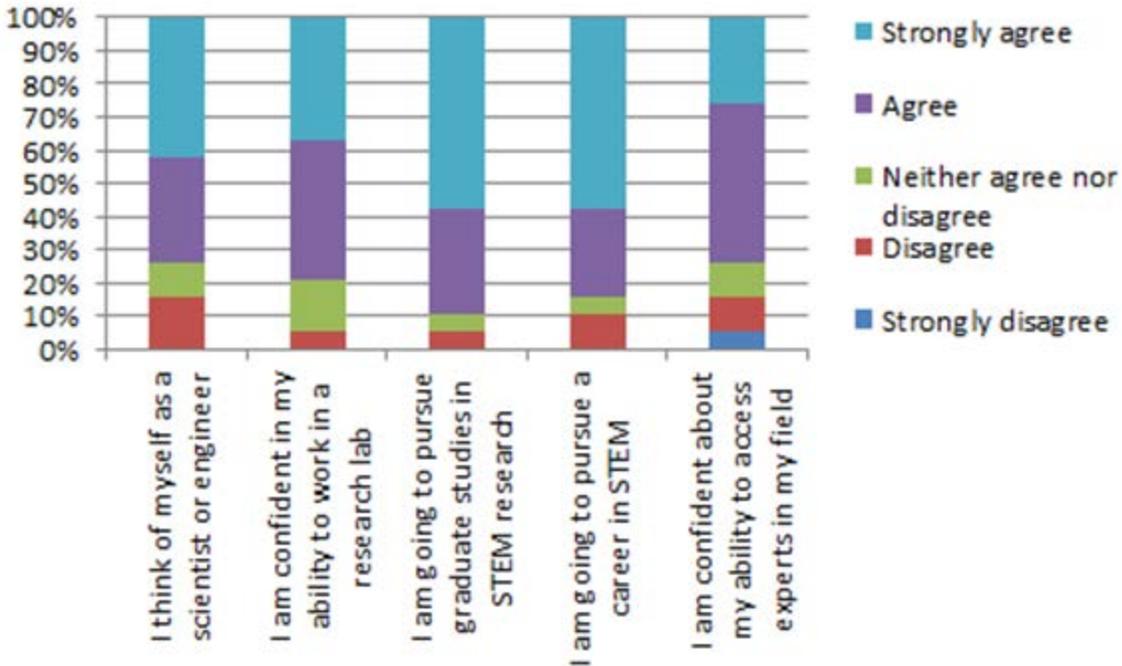


Figure E. Post-REU agreement ratings

Both before and after the REU program, at least 60% (12) of the students indicated they hope to obtain a Master’s or PhD, thus there was no change in their overall educational goals; rather, the program provided students with skills and knowledge to accelerate their preparation for graduate school. Participant views were also similar to before their REU experience regarding work sector, with industry being the most preferred work setting, followed by academia and government. When asked about their career goals, IOU-NA students described their hopes of pursuing graduate education and continuing research. Several hope to conduct work that benefits their Native American communities.

### Conclusion

Students who completed this program have gained essential scientific knowledge related to their projects, professional development skills that will help them excel as engineers and/or scientists, confidence and skills to apply for and succeed in graduate school, and relationships with peers and faculty that will open doors for them throughout the remainder of their academic careers and beyond. The IOU-NA program demonstrates positive impacts on students who would have otherwise not had the opportunity to engage in quality research and be mentored by high-caliber faculty. Past participants in this program have stated that this REU has changed their academic trajectory and opened doors they never knew possible, making it a vital component to supporting the retention of Native Americans seeking STEM majors, considering graduate school and broadening participation in the STEM workforce. Ultimately, the IOU-NA REU program, along with other research programs for URM groups are transformative to communities and Native nations, as well as to our nation’s security and manufacturing edge and diversity in the workforce.



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