Research in Optics for K-14 Teachers (ROKET): A Research Experience for Teachers in Native American Schools

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NSF Research Experience for Teachers, Research in Optics for K-14 Educators and Teachers (ROKET): Enriching Native American Classrooms through Teacher Impact

Abstract

The National Science Foundation (NSF) funded Research Experience for Teachers (RET) entitled Research in Optics for K-14 Teachers (ROKET) (#EEC-1300370 and #EEC-1009496) was a multidisciplinary RET in the Center for Integrated Access Networks (CIAN), an NSF funded Engineering Research Center (ERC) at the University of Arizona (UA). ROKET supported 50 teachers from Native American schools in a 6-week summer research experience over a 7 year period in labs in the College of Optical Sciences and the College of Science. Applying theories of American Indian identity development to teacher development, the goal of this program was to increase cultural awareness in Science, Technology, Engineering, and Mathematics (STEM) classroom curriculum and build professional mentoring relationships to transform Native American classrooms and pique the interests of Native American youth toward STEM careers. The ROKET program collaborated with the American Indian Language Development Institute (AILDI) at the UA. For over thirty years, AILDI has lead efforts to document, revitalize, and promote indigenous languages, which then improves articulation of mainstream science terms to the indigenous population. The collaboration between CIAN and AILDI represented a unique program for science educators working in Native American communities to apply STEM concepts through the lens of native language and culture and develop culturally competent STEM curriculum. In total, 289 applications were received for the ROKET program, with 50 participants selected from 42 different Native American schools across 12 different states. Some teachers were from the same schools as the selected applicants, and a few even participated in the program twice. Forty percent of the participants were Native Americans and 56% were females. Since the program, teachers have attended approximately 25 conferences, several with their students. Program deliverables included a research poster and two STEM lesson plans for their classroom – one with indigenous culture embedded into STEM concepts, and the other based their university research. Additionally, participants received $1500 toward classroom supplies to support the RET lesson plans. Outcomes include increased teacher confidence in performing research, improved laboratory skills, and greater understanding of STEM pedagogical development specifically geared toward Native American culture. Broader impacts of this program on Native American youth involve precollege partnerships developed between teachers and research mentors post-RET, such as student and faculty mentor visits to local participant classrooms at least once a year to support teachers with their RET research lesson plan; a nanophotonics afterschool club for 3rd graders; an afterschool STEM program bringing together precollege teachers, students, parents, and university students, an on-campus

UA optics summer camp with an RET partner school; Frontiers for Young Minds project with CIAN and an RET participant's students; STEM comic book development collaboration with an RET participant as illustrator; and RET STEM education contributions for dissemination on CIAN's Photonics Hub, an online education clearinghouse. Lasting impacts such as these provide engaging academic experiences in STEM for Native American youth; improve teacher-student relationships; and bridge reservation schools, tribal communities, and the universities in the hopes of motivating Native American youth toward STEM careers.

Introduction

The RET Research in Optics for K-14 Educators and Teachers (ROKET – NSF #EEC-1300370 and #EEC-1009496) program was developed by the Center for Integrated Access Networks (CIAN), an NSF funded Engineering Research Center led by the University of Arizona (UA) in partnership with the UA's American Indian Language Development Institute (AILDI) each summer since 2010. This collaboration built on previous successful teacher programs [1]. Additionally AILDI was cited in a study by the U.S. Department of Education as one of the ten outstanding programs for minority teacher preparation in the nation [2]. Pre-college teachers and community college faculty from Native American-serving institutions are recruited to experience optical engineering research and learn about techniques to transmit their research knowledge to their students using innovative methods. Participants take part in AILDI classes tied to science education, basic optics lessons in the Optics Research Workshop (ORW), a tribal science education workshop led by Professor Gregory Cajete [3], and a research project facilitated by esteemed UA research faculty. They are given the opportunity to develop their research experience and knowledge, enabling them to develop hands-on activities tied to their research projects, which they will use in their classrooms. The program provides the resources and support to create inquiry-based curriculum that is culturally relevant; thus, increasing the likelihood of influencing students' propensity towards education and careers in science and engineering. Past RET ROKET teachers have expressed the importance of integrating the excellent Native American culture and language training from AILDI within the context of science through the AILDI course. By learning new scientific content and having the guidance to tie it directly to positive impacts on Native American communities, teachers are enthusiastic to develop lesson plans that bring cutting-edge photonics experiments into their classrooms. One such teacher, returned to her elementary school with a new knowledge of nanotechnology. Using this knowledge she encouraged her students and successfully saw them submit nanotechnology projects to the science fair. The science lessons created by RET teachers have been linked with community participation and practices based on community values, needs, language, and experiences. This is highly valuable since literature on Native Americans and higher education in STEM (Science, Technology, Education, Mathematics) fields supports the claim for the need for a program to promote understanding of how science aids and facilitates Native American issues within the context of their communities and culture [4].

Background

Research Motivation

Of the 4.8 million scientists and engineers in the United States, only 17,000 are American Indian/ Alaska Native (0.3%) [5]. Therefore, the intellectual focus of this RET program is grounded in

the need for more Native American students to pursue STEM fields. There is critical need for Native Americans to positively view the impact science and technology has on their lives, as their land is often located on or surrounding natural resources [6]. This program is specifically designed to increase RET participants' awareness of the impacts optics has on U.S. communities, particularly Native American communities, so that they can return to their classrooms as a mentor to increase students' awareness and pique their interests in STEM fields. A 2008 NACME report highlighted that most minority students are not prepared for STEM fields, and that having a Native American mentor is integral to preparing Native American students for STEM fields [1] [7] [8]. Other literature reveals that common themes central to Native Americans' pursuit of STEM post-secondary education includes: 1) Active, hands-on, small-scale science experiences that are engaging and important (RET lab research project); 2) Having a mentor who can support them in science education to increase the likelihood of pursuing higher education degrees in STEM [1]. These findings and this program are important because optics directly impacts Native Americans and their communities, but this awareness often goes unknown due to the interdisciplinary nature of Optical Sciences.

The training of science educators, from primarily Native American communities, promotes ambitions to pursue science education among Native American students, thus creating the potential for local economic growth [9] [10]. We partnered with the College of Engineering, College of Optical Sciences, as well as teacher participation in a program dedicated to Native American language preservation to establish a cohesive program. These partnerships are important to both the academic communities and the indigenous communities nationwide to demonstrate that stakeholders are coming together to address the need to increase the presence of Native American students in higher education. In addressing the national imperative of increasing underrepresented minorities in STEM, it is therefore critical to prepare teachers serving Native American students in STEM and its impact on their communities. Dissemination of the results of RET participants' research projects through poster sessions and conferences, further increases the efforts to bridge the gap between Native Americans and higher education studies in STEM.

Methods

In the RET ROKET program, teachers participate in an AILDI course concerning language, culture revitalization, and teaching methods to improve science education for Native American students; engage in an interactive ORW to learn optics laboratory techniques, through hands-on experiments with lasers, fiber optics, solar cells, and optical spectroscopy; and participate in applied research with a CIAN faculty mentor where they learn about optical applications of material science, nano-fabrication processes, space optics, and engineering design tradeoffs in telecommunications. Follow-up activities include tracking of classroom implementation and presentations/attendance at national educators' conferences. Additional program activities include workshops by STEM and Native American Education experts: 1) Professor Gregory Cajete's (UNM) renowned "Science in Native American Education," and 2) Native Nations Institute's "Governance and Leadership on Native Lands." These activities support the integration of Optics into Native American cultures and communities. They have the potential to transform Native American pre-college and community college classrooms while significantly

impacting a population shown to lag behind other underrepresented minority groups in college matriculation and retention, particularly in STEM.
The program is concluded with a presentation by the teachers of their project using a poster the teacher has created. All members of the College of Optical Sciences are invited and encouraged to attend and engage the teachers about their projects. The teachers are required to create and submit an innovative lesson plan that incorporates aspects of their research experience in the classroom. Additionally, teachers submit a classroom supply budget request allowing them to stock their classrooms with $1,500 worth of new science and education supplies that can be used in combination with what they have learned from the experience.

Results

Since 2010, 50 pre-college and community college teachers in a STEM discipline serving Native American communities and students participated in CIAN's RET ROKET program at the University of Arizona. The participants included 28 (56%) female teachers and 20 (40%) Native American teachers; they served over 20 different tribes in 12 states. Most of the teachers worked with the Navajo (13) and Tohono O'odham (10) tribes. Other tribes teachers worked with include: the Nez Perce (3), Sioux (3), Zuni (2), Akimel O'Otham (2), White Mountain Apache (2), San Carlos Apache (1), Blackfeet (2), Paiute (1), Hopi (1), Menominee (1), Fond du Lac band (Lake Superior Chippewa) (1), Colville Indian (1), Potawomi (1), Stockbridge Munsee (1), Pueblo (1), Muckleshoot (1), Umatilla (1), and Assinboine (1) tribes, and 2 participants served multiple tribes. The participants taught Native students from Kindergarten through community college. Most participants taught STEM subjects to students in High School (28), followed by students in elementary school (16), middle school (13), and community college (5); although, 10 teachers served multiple grade levels, with students from K-12th grade.

Participant Perceived Attitudes

Following CIAN's 2010-2016 RET ROKET program, participants were asked to complete a survey administered via surveymonkey.com. Thirty-six participants completed the pre- and post-survey, which provided data for comparing changes in teaching attitudes and skill confidence, as well as general attitudes and perceptions about the program and its effects. Participants were asked to report their attitudes about their own teaching skills. For instance, participants were asked to rate their agreement with the following: I am motivated to expand on the instructional techniques that I use, I am motivated to change the way I use hands-on materials and manipulatives in my teaching, I am motivated to use more technology in my teaching, I consider myself to be a "subject matter expert" in my main teaching field, I consider preparing students for the kinds of expectations they will encounter in a work setting as an important part of my job. Though individual attitudes saw some changes, shifts in attitude for the overall respondent group were minor; most respondents agreed with all statements to a "Moderate extent" or "Great extent" both before and after the program (See Figures A and B).

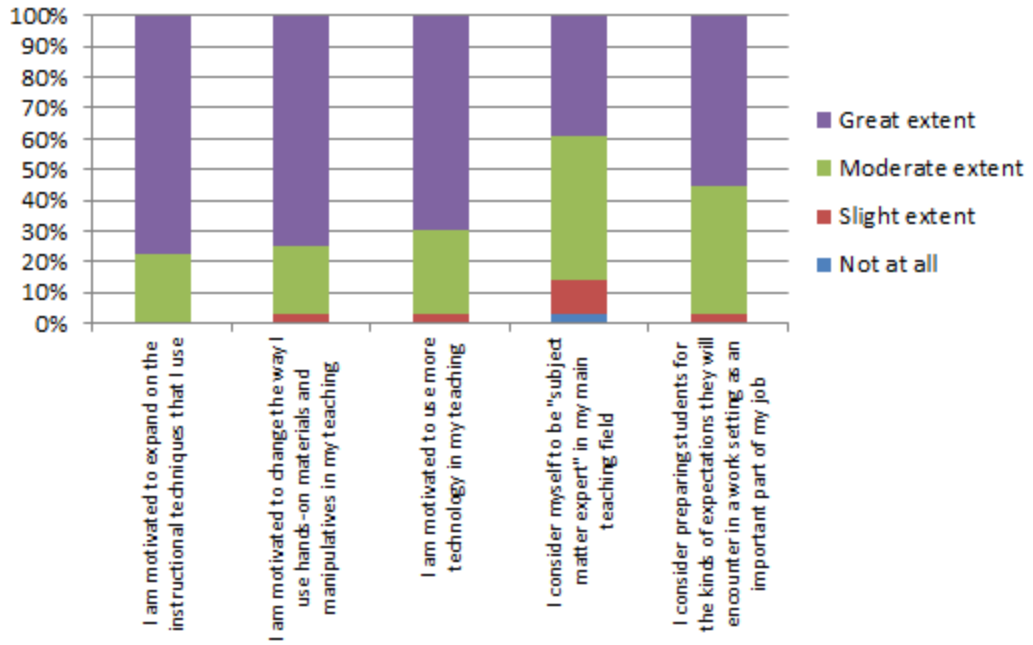

Figure A. 2010-2016 Pre-Program Attitudes

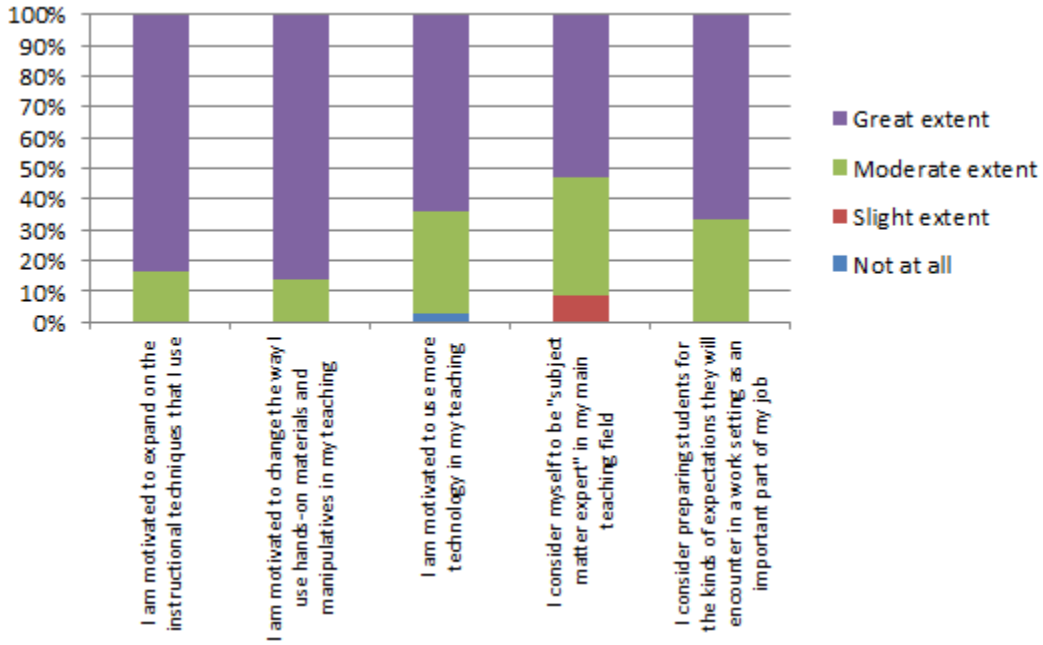

Figure B. 2010-2016 Post-Program Attitudes

Participant Perceived Confidence

Participants were also asked to indicate their level of confidence in a specified set of skills in order to assess if the RET ROKET program boosted their confidence in these skills. Pre- and post-program survey responses were very comparable - 80% or more of ROKET teachers indicated that they were “Moderately confident” or “Very confident” in the specified skills, both before and after the RET (See Figures C and D). Skill areas of greatest confidence, post program,

included: Knowledge about the application of the subject to everyday life, Ability to incorporate technology (computers, the Internet, DVDs, etc.) into your teaching, and Ability to make presentations at teacher inservices or professional meetings.

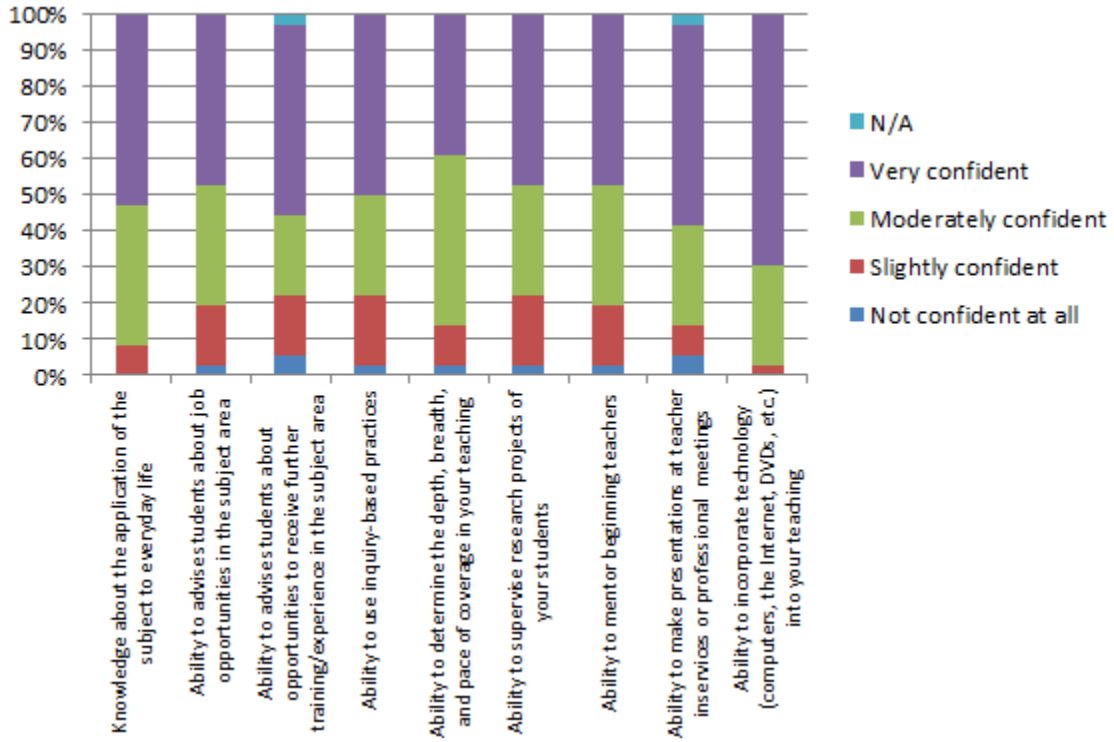

Figure C. 2010-2016 Pre-Program Confidence

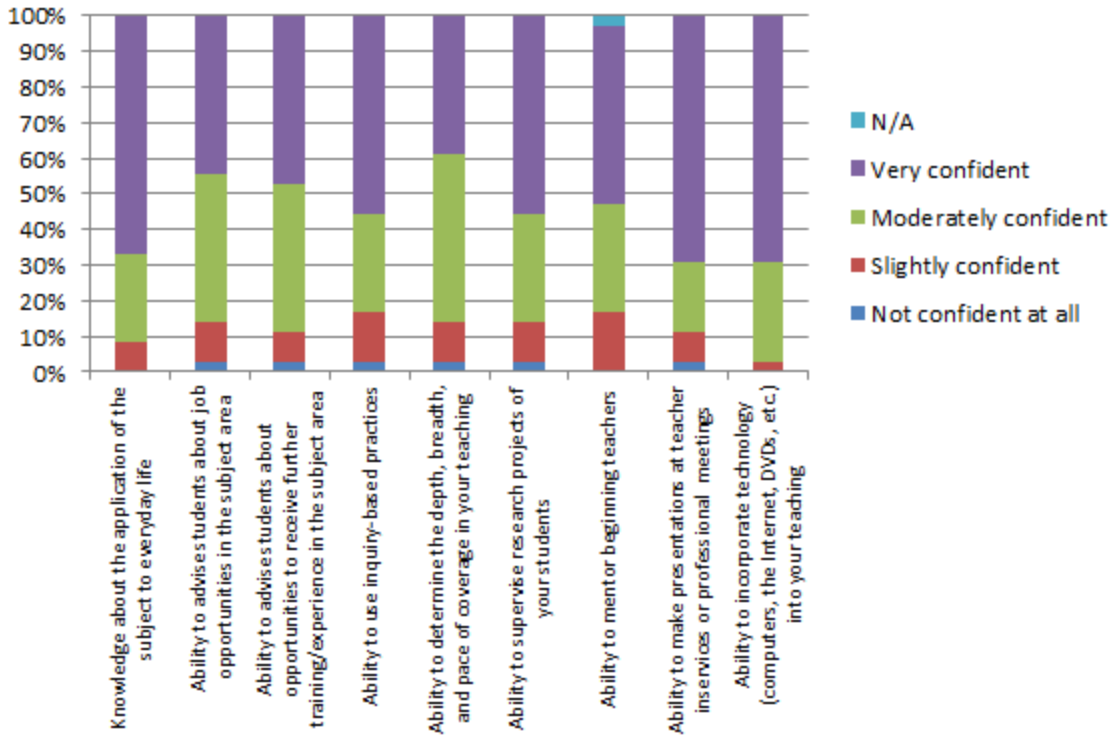

Figure D. 2010-2016 Post-Program Confidence

Participant Reported Impacts
Participants provided qualitative data as well, regarding skills and positive experiences, the most rewarding aspects of the program, the most challenging aspects of the program, and potential improvements and changes to the program.

Participants described many skills and positive experiences that they took away from the program, including:

- "Ability to design a Problem Based Learning unit, understanding of possible selves theory, development of an outreach program for an NSF grant proposal, expanded professional network."
- "Language incorporation, traditional ecological knowledge concepts, organic chemistry concepts, new teachers to network with, and probably most important, I am energized and enthused to return to the classroom."
- "I have the ability to explain, in detail, the complicated instruments/equipment used in scientific research, such as the Scanning Electron Microscope. I can explain the use of equations for predicting and explaining data. And I can explain the sense of discovery, after experiencing the cutting-edge research."
- "Understanding the analysis of different indigenous languages as well as thinking more of the perspective from the culture of the student and how to use that knowledge to switch back and forth from Western perspective to their own cultural heritage."

Some participants described the most rewarding aspect of the RET program as the following:

- "The interaction with professionals in all aspects of the program. I've felt disconnected in my teaching grade 8 science as far as the real world goes. RET has changed that."

- "Working with different people of different backgrounds and perspectives. Learning new software and computer technologies. Being allowed to work in the lab with the Grad students."
- "The most rewarding part of the program was the family I met, my fellow classmates who share common aspirations and calling, to bring a difference in the lives of Native American students. We did learn from each other and the entire experience which has a ripple effect, from the university mentoring us so we can better serve our students, our students to reach out to others and hopefully be a University of Arizona student."
- "The cooperative nature of the lab in which I worked because I had extremely intelligent and knowledgeable people around me who were willing to share their expertise and time."

Participants identified some challenging aspects of the program, such as:

- "The learning curve and the application of some aspects of research."
- "It is kind of challenging to learn the lab high context in such a short period of time."
- "Being away from home was challenging because I had to remember to be a student living the dorm life all over again."
- "Lack of knowledge of the lab research being conducted. I felt challenged because I had a lot to learn in a very short amount of time."

Survey respondents were also asked to propose improvements and changes for next year's program. They suggested the following:

- "I would like to spend more time in the lab."
- "Better use of management time particularly in the area of scheduled meetings and events."
- "The only addition I would like to make is that it would help in the lab setting to group teachers at the same levels together. High school with High School and Elementary with Elementary."

Despite the challenges, 100% of the participants agreed that the summer research experience positively impacted them, and 83% also stated that they learned at least a moderate amount about optics compared to what they knew before. Additionally, 86% of the respondents indicated that interaction with their mentors was "Sufficient enough" or "More than sufficient." Also, 78% agreed that the research experience was "Structured enough," such that there was a good balance between structured learning opportunities and freedom to pursue personal creativity and projects. Participants were asked about various aspects of the summer research experience (See Figure E) as well, with general attitudes reflecting an extremely positive experience for most respondents; a majority of responses were "Strongly agree," and the following statements received 75% or more "Strongly agree" responses: "My position provided me with opportunities for learning and professional growth", "There was a positive value to the research project in which I was engaged", "I would be interested in another research experience at CIAN", and "I would recommend this program to my colleagues."

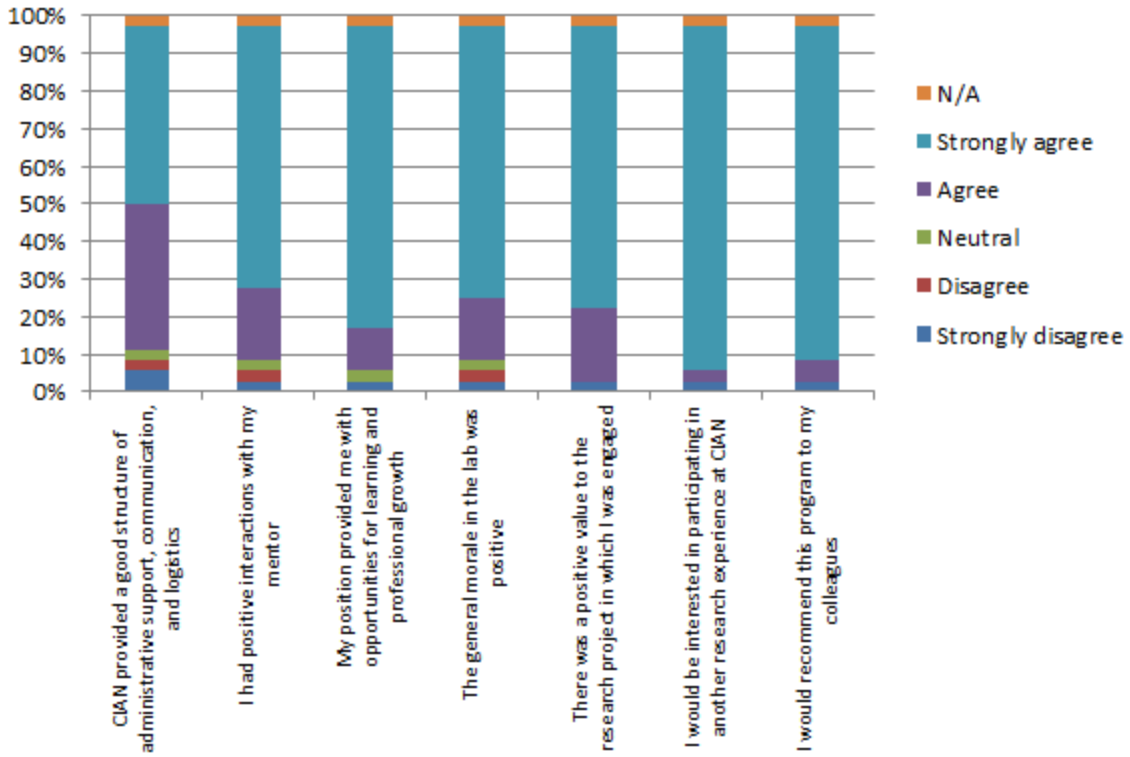

Figure E. 2010-2016 Aspects of Experience

Participant Reported Perception of Experience
ROKET participants were asked to rate their overall experience, to which 89% indicated it was "Excellent" (97% indicated it was "Good" or "Excellent"). Final qualitative feedback was collected to assess what might be done to further meet teachers' needs. Among several comments of gratitude were the following:

- "Excellent program, highly recommend to my peers."
- "Thank you. I cannot remember a better, more valuable summer experience. I hope I will be able to repeat it next summer."
- "The CIAN-ROKET experience was great! The information through CIAN's program is valuable as I have personally grown mentally in my profession as an educator. I thank you for the opportunity to learn and expand upon my knowledge."
- "I am very excited to share this experience with my students, and I am looking forward to using all the tools and knowledge I gained. Thank you CIAN. You made me realize that no one is too old to learn and this opportunity was a big blessing for me and my community."
- "This is an excellent program. It was a wonderful opportunity and I am so glad that I was able to participate. I got a great deal out of it. Thank you so much for this opportunity."

Conclusions

The RET ROKET program creates a community of practice that will support teachers to build their expertise in content and delivery of science, mathematics, and technology skills. Exposing teachers to the various applications of Optics is essential in motivating Native American students

toward future careers in Optics, which has cross-cutting concepts that are already embedded in Reservation school curriculum. For instance, Optical Sciences is integral to research that is helping Native American communities address the prevalence of high astigmatism in Native American youth, especially in Tohono O'odham Nation [1]; and Internet connectivity and speed on reservations is a current issue causing social and education isolation [7]. Optical Sciences is critical to solving these problems. Furthermore, the RET ROKET program bridges the academic science community and Native American-serving institutions. ROKET creates an environment where the teachers are once again the "students" and intellectual discussions can transpire without assessments being administered or any grade attached. Faculty and graduate student mentors benefit as well, not only from hands-on research assistance but also from contact with those shaping their future students, gaining insights into Native American cultures (in particular the challenges of fully integrating science into students' daily lives). The activities in this program were developed to cultivate partnerships that last beyond the summer by creating a program that develops professional networks among pre-college educators, UA faculty, and students who are active, available, and involved. Ultimately, CIAN has developed a strong infrastructure that has enriched Native American pre-college and community college classroom curriculum, mentorship, and student engagement.

New Opportunity

CIAN received a new NSF RET grant in 2016 called the Optics Research Experience for Teachers in Native American Schools (O-RETiNAS). CIAN's original initiatives with the ROKET program will continue with new and improved aspects in the new O-RETiNAS program. For example, O-RETiNAS is 8 weeks instead of 6 weeks and has incorporated not only a research lab component, but an industry practicum to further engage teachers' abilities to return to their classrooms with real-world experience. CIAN is enthusiastic to continue engaging this group of educators and will continue to improve programming and opportunities available for these educators.

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