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Developing STEM Curriculum Units to Engage 4th-8th Grade Navajo Students as Part of In-Class Outreach

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ABSTRACT: The Native American Astronomy Outreach Program (NAAOP) at Lowell Observatory is an in-class STEM enrichment program that pairs astronomers with 4th-8th grade teachers at Native-serving schools in northern Arizona. The astronomer works with the teacher to present hands-on astronomy activities to their class with the goal of getting students excited about STEM and STEM careers. Over three school years (2018-2021), a special collaboration with teachers at the Navajo Nation's Kayenta Unified School District was used to develop and implement curriculum units for each grade level with potential for a high impact on students. The curriculum used Project Based Learning to better enable students to see themselves as scientists, and it included cultural and local connections related to the science content to encourage students to see science as relevant to themselves. Although impacted by the COVID-19 pandemic, student surveys suggest that these curriculum units along with the other components of the program had a positive impact on students' interest in STEM.

INTRODUCTION

The Native American Astronomy Outreach Program (NAAOP, originally Navajo-Hopi Astronomy Outreach) at Lowell Observatory (LO) is an in-class STEM enrichment program started in 1996 by Drs. Amanda Bosh and Hunter, astronomers at Lowell Observatory. Today NAAOP pairs astronomers with 4th-8th grade teachers at Navajo, Hopi, and, as of 2020, Apache Nation schools, usually for one school year. The astronomer travels to the school periodically throughout the school year and carries out hands-on astronomy activities in partnership with their teacher. The teacher-astronomer partnerships, modeled after the Astronomical Society of the Pacific's Project ASTRO program (https://astrosociety.org/education-outreach/k-12-science-teachers/project-astro.html), are the heart of NAAOP. From this we created a unique program tailored to the educational needs of remote Native teachers and students. The goal of the program is to help teachers get kids excited about STEM and STEM careers, and it was founded in the belief that scientists can have something useful to contribute to teachers and their classrooms (e.g., Pompea and Russo, 2021).

In this article, we first describe the different components that define the outreach program. Then we describe a curriculum development initiative undertaken as a collaboration between NAAOP and the Kayenta Unified School District (KUSD) on the Navajo Nation aimed at increasing the impact on Navajo students' interest in STEM.

KEY ASPECTS OF THE PROGRAM

The Need. NAAOP chose to work exclusively with Native students because of the high dropout rate from high school (9.6% compared to 4.1% for Whites; U.S. Department of Education, National Center for Education Statistics, 2021) and the low college enrollment rate (about half that of Whites; U.S. Department of Commerce, Census Bureau, 2019). Also, the poverty rate is high: 28% for Native Americans compared to 10% of Whites (DeNavas-Walt and Proctor, 2015). For example, in most Navajo Nation school districts, most or all students receive free or discounted breakfasts and lunches. And yet, tribal nations face environmental decisions and pressure for economic development that would benefit from a STEM-literate constituency.

NAAOP chose to work with the Native Nations in northern Arizona because of their proximity to Flagstaff where Lowell Observatory is located. For example, there are over 150 public, private, and Bureau of Indian Education schools that receive funding from the Navajo Nation under the Johnson O'Malley program. All of these school systems struggle to ensure high-quality learning experiences and to retain students from year to year. By working with teachers in rural communities across the Navajo Nation, NAAOP strives to make a positive contribution to STEM education in schools with minimal opportunities for outreach.

The Target Age Group. Middle school is a crucial age as students transition from the inherent curiosity of little kids to the ingrained disinterest of high school students (Potvin and Hasni, 2014). It is at this stage that one can have the most impact on future career options and attitudes towards STEM (Wyss et al., 2012). Furthermore, in these grades, according to current Arizona Science Teaching Standards, students should acquire a basic understanding of Earth and the Universe and be familiar with such terms as constellations and planets. In addition, our program can perhaps have the strongest impact on elementary and middle school teachers, who generally must teach all subjects and are sometimes hard-pressed for the time to engage in hands-on science activities (McClure et al., 2017). Thus, 4th-8th grade was chosen as the best focus for influencing students' interest in STEM, and supporting teachers' efforts to integrate high-quality STEM teaching.

Special Considerations. Each astronomer takes their cues on how to participate in the classroom from their partner teacher. In addition, NAAOP's team members Little and Pipe have suggested additions that stem from their own experiences. For example, 1) Many parents struggle with the expense of feeding their families, and hunger is distracting. So sometimes our astronomers and educators bring healthy snacks to the classroom on their visits. And, 2) Kids have sometimes been welcomed back to school after the winter break with a little bag for each student containing a pencil and a piece of paper with encouragement to do well in school written in Navajo. These gestures, although small, can help to build a connection between the students and the astronomer that increases the impact of the educational activities.

What Makes NAAOP Unique. There are several components of NAAOP that make it unique. One key aspect is the willingness of team members to drive long distances to get to remote schools. The schools that NAAOP works with are located a 1.5–6 hour drive from Flagstaff, being in Arizona, New Mexico, and Utah, and a major part of a classroom visit is just getting there and back (see Figure 1).

Another key component is that NAAOP provides all of the materials for the activities. Schools vary considerably, but many do not have funds for the supplies needed for hands-on STEM activities. Furthermore, the nearest grocery store or craft store can be a long drive away, and obtaining supplies through the school can be frustrating due to procedural complexities.

Another key aspect of our program is that NAAOP works with both teachers and their students. We want to introduce teachers to engaging astronomy hands-on activities that can become part of their toolbox going forward. But NAAOP team members also participate as co-teachers in the classroom and students are often excited for their NAAOP partner to visit.

Finally, a key ingredient NAAOP brings is our expertise in astronomy and our enthusiasm for sharing what we know with the teachers and students.

THE NAAOP-KUSD COLLABORATION

Motivation. In 2016 NAAOP became aware that for Native students to seriously consider STEM careers for *themselves*, the students had to be able to see themselves as scientists (Camp 2016). The majority of Native middle school students, when asked to draw a picture of a scientist at the beginning of the school year, inevitably described a White man in a lab coat with a foreign accent. How can this apply to them? And when asked what careers they saw for themselves, they only listed the jobs they saw around them.

A committee of several teachers we had worked with in the past recommended that we undertake curriculum devel-

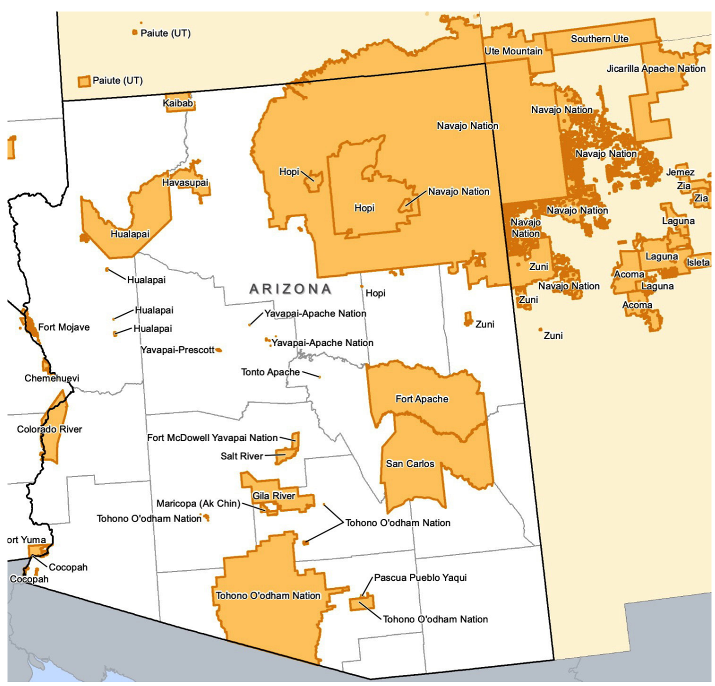

Figure 1. Locations of tribal lands in Arizona. Note that the Navajo Nation extends into New Mexico, Colorado, and Utah. Flagstaff is just west of the southwest corner of the Navajo Nation. From the US Environmental Protection Agency website.

opment using Project Based Learning (PBL). Such an approach gives students more opportunity for self-direction that enables them to engage in the process of science, a crucial step in bringing under-represented and racialized students into STEM fields (Blumenfeld et al., 1991; Nelson-Barber and Estrin, 1995; Cajete, 1999; Gay, 2000; Thomas, 2000; Stephens, 2001; Grant, 2002; Barak and Dori ,2005; Donovan and Bransford, 2005; Barnhardt, 2005; Bang and Medin, 2010; Camp 2016; De Pree and Grossman, 2017; Feder, 2020).

Furthermore, our advisors recommended integrating local and cultural connections throughout the lessons so that students could see STEM as relevant to their lives. The Native peoples of northern Arizona have strong foundational beliefs in traditional knowledge regarding the universe and astronomical objects that is very much alive today. Through discussion with our partners, we came to understand that students would be more receptive if they saw that there were connections between STEM and their own lived experiences and community cultural knowledge (Nelson-Barber and Estrin, 1995; Cajete, 1999; Gay, 2000; Stephens, 2001; Barnhardt, 2005; Bang and Medin, 2010; Feder, 2020).

Our advisors also recommended that the new curriculum should be a coherent package that is clearly and explicitly aligned to state (currently Arizona), Common Core, Next Generation Science, and tribal (currently Navajo) standards. The newly developed curriculum also incorporates reading, writing, and math, and each unit has a robotics component to illustrate the central lesson of the unit that promotes facility and comfort with technology (Elliott, 2012; Smith, 2014; Mareco, 2017). Each unit requires the students to produce posters about their project that they present to Lowell staff and mentors at a poster session at Lowell Observatory when the class comes on their field trip. These features create units that are more useful to teachers and more aligned to the expectations of principals, thus enhancing the likelihood that the units will be used consistently from year to year.

In response to these recommendations, NAAOP carried out a pilot project, creating a week-long 5th grade unit on characteristics of the planets and using it in several of the classrooms participating in NAAOP in 2016-17. In reviewing this first attempt, the advisory committee recommended that we carry the curriculum development on to include all of the grades with which NAAOP works.

In order to carry out this curriculum development and determine its impact, NAAOP approached the KUSD on the Navajo Nation about a collaboration between NAAOP and their 4th through 7th grade teachers (8th grade was added a year later). We proposed a 3-year collaboration, which the KUSD School Board approved. In the spring of 2018 we assembled the diverse team of educators and scientists listed in Table 1.

Furthermore, the Kayenta Middle School (KMS) principal agreed to keep students together as a cohort over the three years, so that they would always be in classrooms of the teachers we were working with as they advanced from 4th grade (KES) through the middle school years (KMS).

Table 1. *Roles of Team Members.*

Team Member	Position	Role
Hunter	Astronomer, LO	Co-founded and managed NAAOP, oversaw collaboration, partnered with teachers, headed the Navajo IRB application
Castagno	Founder and Executive Director of Just Perspectives, LLC	External Program Evaluator for NAAOP, created and collected surveys and analyzed data
Gonzales	Education Manager, LO	Wrote the curriculum units, partnered with KUSD teachers
Tallsalt	Educator, Navajo Nation	Cultural consultant to NAAOP, contributed Navajo cultural connections and vocabulary to the curricula, contributed to camps
Little	Multi-Cultural Outreach Supervisor, LO	Initiated many aspects of the program and partnered with KUSD teachers
Brown	NAAOP Educator, LO	Contributed to all aspects of NAAOP and partnered with KUSD teachers
Pipe	NAAOP Educator, LO	Contributed to all aspects of NAAOP and partnered with KUSD teachers
Greyeyes	4th grade teacher, KES	Contributed to the curriculum, partnered with NAAOP
Marsh	4th grade teacher, KES	Contributed to the curriculum, partnered with NAAOP
Smith	5th grade teacher, KMS	Contributed to the curriculum, partnered with NAAOP
Paulson	5th grade teacher, KMS	Contributed to the curriculum, partnered with NAAOP
Yazzie	6th grade teacher, KMS	Contributed to the curriculum, partnered with NAAOP
Black	6th grade teacher, KMS	Contributed to the curriculum and Winter Camp, partnered with NAAOP
Saganey	7th grade science teacher, KMS	Contributed to the curriculum, partnered with NAAOP
Cole	8th grade science teacher, KMS	Contributed to the curriculum, partnered with NAAOP

In the summer of 2018, Lowell Observatory's Gonzales, who had worked as a middle school teacher and who is trained in PBL, constructed the curriculum units, and our Navajo cultural advisor Tallsalt developed the parts that provide Navajo (Diné) cultural connections and satisfy Diné standards. She also included Diné vocabulary.

In Y1 (2018-19 school year) of the collaboration, each KUSD teacher partnered with a Lowell astronomer/educator to carry out the curriculum unit in their classroom. At the end of the year, the teachers and their partners met and offered suggestions on how to improve the units. They pointed out places in the lesson plans that needed more explanation, additional outside resources (such as YouTube videos) that were useful to expand on the lesson, additional activities

Table 2. *Summary of components of program.*

Teacher-astronomer partnerships	On-going throughout school year
Curriculum Units 4th grade – Wind erosion and sand dunes 5th grade – Characteristics of the planets 6th grade – Energy from the sun and ecosystems 7th grade – Contained ecosystems in space 8th grade – Chemistry of Venus and Mars	On-going throughout school year
Teacher and astronomer curriculum training	Fall
Book Club	On-going throughout school year and Summer camps
School Star Parties	Fall and Spring
Field Trips to Lowell Observatory Poster session Role models	Spring
Summer camps – 6th and 7th grades	Summer
Winter camp – all grades	January 2021

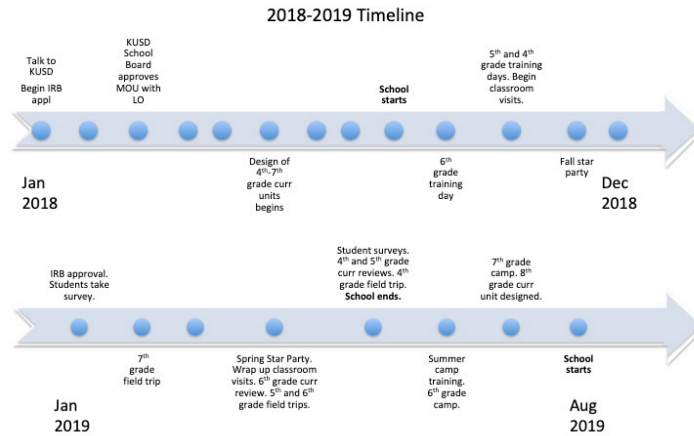

Figure 2. Timeline of activities in Y1. Note that there was no curriculum training workshop for 7th grade because Gonzales, who created the unit, was working directly with the single 7th grade teacher. Also, 8th grade was added in Y2.

that they found useful (such as having the class "program" a person to make a PB & J sandwich before they began programming the robot), or additional or better ways to include cultural connections (such as the Navajo philosophy of learning, relevant stories and books). In Y2 (2019-20), the teachers and their partners carried out the revised units. In Y3 (2020-21), NAAOP worked with other interested 4th-5th grade teachers (and again with the 8th grade teacher). These new teachers partnered with Lowell astronomers/educators and our veteran teachers acted as their mentors. The collaboration was completed with the 2021 Summer camps. The various components of the program are summarized in Table 2, and a timeline for the activities in Y1 is shown in Figure 2.

The Curriculum Units. Here we describe the five curriculum units. They were designed to be carried out in one week, requiring approximately several hours per day, although some of the classroom experiments require a longer period of time to watch plants grow or sand dunes evolve. However, in most cases it was more convenient to the astronomer to carry the unit out over a longer period of time, with classroom visits weekly or every few weeks. A typical individual classroom visit might start with a review by the teacher of the key concepts and vocabulary from the previous visits and then an introduction by the astronomer to the current activity. The two would help the students through the activity and then the teacher would summarize the key concepts. Students often kept a notebook where they would write definitions of new words, paste in handouts, and record thoughts or results from the activities. The teacher might also have the students watch videos or read materials between visits to reinforce the new concepts. Once the curriculum unit was finished, the astronomer would often return to assist with poster preparation or to bring activities on other astronomy topics. Thus, the participation by the astronomer would usually begin after the training workshop in the Fall and continue until near the end of the school year.

The 4th grade curriculum unit focuses on wind erosion and compares sand dunes on the Navajo Nation with those on Mars (see Figure 3). During the first two years of the collaboration, the two 4th grade classes took their anemometers, part of the equipment and materials supplied to the class, on a field trip to nearby Monument Valley to explore wind speeds in and around real sand dunes. The in-class lab consisted of recreating sand dunes with a fan to produce wind so that students could watch their sand piles evolve. Their final poster consisted of pictures of sand dunes on Mars with students' explanation of what is happening on that planet. The technology component of this unit was to program Ozobots, simple small robots, to follow a course through the sand dunes.

The local cultural connection within this unit is strong since sand dunes today are taking over grazing land and swallowing houses on the Navajo Nation. Students and teachers talked about having to shovel sand from around their out buildings. The classes watched an impactful video *A Record of Change: Science and Elder Observations on the Navajo Nation* (Redsteer & Wessells 2017) that describes the changes that have taken place over time and gives the students the big picture view of the problem.

The 5th grade unit is on characteristics of the planets. Here students learned about the characteristics of Earth, Mars, and Venus. For the in-class lab, they recreated key elements of each environment in a bottle that also contained yeast. A balloon sealing the top of the bottle was used to measure the success of life in that environment. The final poster was a "travel brochure" for either Mars or Venus that explained how the students imagine enabling human beings to live on that planet. The students were asked to consider what elements of their culture they would take with them to better enable them to live there. The technology component was a Sphero robot that was programmed through a tablet to explore a planetary surface of their making.

LOWELL
OBSERVATORY

Lesson Title/Creator	Introduction to the Scientific method and Erosion TG/18
Type of Lesson	Science Inquiry-Project Based
Scientific Topic	Wind Erosion
Unit Standards	New Arizona Standard: 4.E1U1.6: Plan and carry out an investigation to explore and explain the interactions between Earth's major systems and the impact on Earth's surface materials and processes. NGSS PE: 4-ESS2-1. Make observations and or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation. SEP: Make observations and/or measurements to produce data to serve as a basis for evidence for an explanation of a phenomenon DCI: Water, ice, wind, living organisms, and gravity break rocks, soils and sediments into smaller particles and move them around. CCC: Patterns Old AZ Science: Strand 6: Concept 2: PO 1 – Identify the Earth Processes that cause erosion. PO 2 – Describe how currents and wind cause erosion and land changes. Common Core (Reading, Writing and Math): CCRA: R.1, R.2, R.10. CCSS: W.4.1B, W.4.1.D. CCSS: 4.MD.A.3, 4.MD.A.2. Arizona Mathematics: Model with Mathematics 4.MP.4
Lesson Length	90 Mins/day

Prior expectation from the learner	Students may not know how to explain erosion. Students have seen examples of erosion in everyday life.
Summary of Unit objectives (goal)	Students will explain erosion processes on Mars with satellite images. Students will also cite evidence from text and experiment.
Assessment (briefly describe)	Students will be assessed by pre/post tests and a project rubric.

Figure 3. First page of 4th grade curriculum unit.

The 6th grade unit is on energy and energy transfer in ecosystems. This unit focused on the Sun and the path through which the energy that comes to us in the form of sunlight powers life on Earth. The students also learned about life in extreme environments on Earth and what this might mean to life elsewhere in the solar system. Navajo students were reminded of the prominent place of the Sun in their culture and the role it plays in everyday life.

Gonzales devised a game in the form of a race for survival for this unit. Each student team had "sunlight runners" who relay light between the sun and producers, the "nature" students aligned poker chips on water and carbon dioxide molecules to ensure that water and carbon dioxide get to the producers, the "producer" students took the carbon dioxide and water from nature and the sunlight from the sunlight runners to make glucose, the "primary consumers" are the producers once the glucose molecule was intact and made a lipid molecule, and "humans" ate the consumers by receiving the lipid molecule from the consumer and making a glucose molecule. Students learned about the transfer of energy and also about the limiting factors in the cycle. For example, this game can be used to demonstrate what happens if an asteroid throws up a lot of dust into the atmosphere, interrupting the amount of sunlight getting to Earth.

The students applied what they learned to create an energy cycle for life in the ice-covered oceans on Titan, a moon of Saturn, or Europa, a moon of Jupiter. As preparation, they read *Life Under Ice: Exploring Antarctic Seas* by M. Cerulio and B. Curtsinger. The student posters illustrated their imagined energy cycle on Titan or Europa (see Figure 4), and Ozobots traced a sketch of the cycle.

The 7th grade unit is on human made and contained ecosystems in space. The students learned about the carbon, nitrogen, and water cycles on Earth. They designed and created an ecosystem in a sealed bottle and observed the plants and water levels for four weeks. In fact, the students were able to keep the plants that they set up in their artificial environment during the first year of the pandemic alive and growing into the second year of the pandemic. They then transplanted the plants into a larger terrarium, and talked about using the school's greenhouse. The students had to think of ideas on how to create systems that can be self-contained and applied what they had learned to the challenges of living in space, specifically how to fit carbon/nitrogen/water cycles in a spacecraft and deal with limitations on weight. Ozobots illustrated how robots might facilitate the recycling that must take place on the spacecraft.

The 8th grade unit is on the chemistry of Venus and Mars. Students learned about the periodic table and that the elements came from the Big Bang and nuclear fusion in stars. They read *The Disappearing Spoon* (young reader edition)

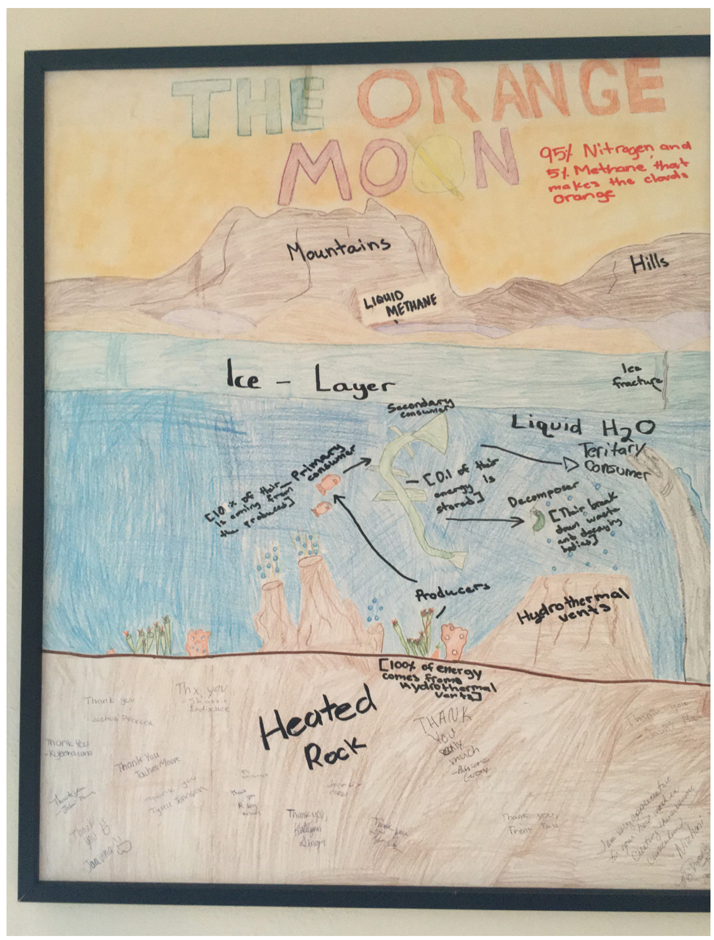

Figure 4. Poster from one of the 6th grade groups on a possible energy cycle on Titan, a satellite of Saturn, Spring 2019. The students wrote "thank you" on the bottom and presented it to NAAOP at the end of their field trip.

by Sam Kean, and watched the astronomer create a spoon from gallium that disappears when used to stir hot tea. They learned about different kinds of rocks and the minerals in them, how the physical and chemical properties of the elements help scientists identify substances in the universe, and how chemical changes create substances with different characteristics. Then they were introduced to the chemical mysteries presented by Mars (the red color of the soil and rocks) and Venus (metal frost deposits found at high elevations). Their posters illustrated their hypotheses on the processes taking place on Mars or Venus.

Other Components of the Program. In addition to the in-class curriculum activities, the partnership with KUSD included field trips to Lowell Observatory, school star parties, Native STEM professional role models, Book Club, residential Summer camps at Lowell Observatory, and an online Winter camp.

Training Workshops. At the beginning of the first school year, we held workshops by grade level in which Gonzales and Tallsalt provided an overview of the curriculum units to the KUSD teachers and their NAAOP partners. We held a virtual version of these workshops at the beginning of Y3 for the new KUSD teachers, led then by the now experienced teachers and NAAOP staff.

Book Club. Reading is critical to students' success in education and beyond (e.g., Ritchie and Bates, 2013). So NAAOP started Book Club, first in the Summer camps and then in the classrooms we were working with. In Book Club students read a book that is engaging and somewhat related to what they are doing in class. For example, the 4th graders, who were studying erosion and sand dunes, read *Out of the Dust* by Karen Hesse, which is about a young girl and her family during the American dust-bowl. The other grades have read *Children of Time* by Adrian Tchaikovsky, a science fiction story about humanity's last survivors escaping Earth's ruin to find a new planet to live on. Another popular book has been *Race to the Sun* by Rebecca Roanhorse, a fantasy adventure with Navajo heroes. One of the 6th grade classes in Y2 became so excited about reading that they asked for more and more books and were on their fourth book when school was closed for COVID-19 in Spring of 2020. Black, their teacher, reported that she had seen a large increase in the vocabulary the students used in talking to her.

Star Parties. The first year of the collaboration, we held a Fall star party and a Spring star party for the 4th graders and the entire middle school. We have portable telescopes, binoculars, and a laser pointer for night sky observing. We also hosted inside activities including Tallsalt talking about Navajo constellations, a demonstration of a software program for designing and flying a spacecraft, making Navajo planispheres, and assorted other activities for parents and students to do together. We also added hands-on activities for early learners. Families would bring their babies along and we provided hands-on space related activities so that it became an inclusive event for elders and pre-K ages. At the Spring star party, the students shared their project posters with their parents. The KUSD teachers wanted to share these star parties with the entire Kayenta community and so they made arrangements for us to hold the Spring 2020 star party at the rodeo grounds with food and a poster area. However, the COVID-19 pandemic was in full swing by then, school was closed, and that star party had to be cancelled.

Field Trips. In the second semester of each school year the teachers were invited to bring their class on a field trip to Lowell Observatory in Flagstaff. The school was responsible for the transportation, bus driver, and chaperones, and NAAOP provided everything else. Typically, students arrived in time for lunch at Lowell and spent the afternoon on their poster session – first practicing introducing themselves and giving their talks and then doing it for real as Lowell folks and special role models came by their poster. The students also toured Lowell and would usually get a special presentation from Lowell's Public Program staff. In the evening, they joined the public in viewing through the telescopes that are part of Lowell's Giovale Open Deck Observatory and looking through the historic Clark refractor that Percival Lowell used to view Mars. Although there were variations by grade level and weather, the students typically also got some practice in using a portable telescope and finding their way around the night sky, and we did inside activities that related to their classroom work. And, of course, there was hot chocolate. The next day the students toured either Lowell's 4.3-meter research telescope or the Navy Precision Optical Interferometer. The 8th graders also toured the ICE Lab at NAU. After lunch, the class returned to their school.

Role Models. There is no substitute for seeing people like yourself who are engineers or scientists in real life to help you see that you too could aspire to a STEM career. So NAAOP approached companies in Flagstaff, Arizona, and beyond about having their Native engineers/scientists serve as role models for students in our program. Navajo engineers from Raytheon in Tucson in southern Arizona came to several of our classes' field trips. They told the students their stories, including mistakes they made and how they overcame them and what they love about their work. They also talked with the students about their posters. Folks from W. L. Gore and Associates in Flagstaff also participated in the field trips, and JPL, Boeing, and BNSF Railway are organizing with the intention of participating in the future.

Summer Camps. In the summr of 2018 NAAOP initiated residential Summer camps in Flagstaff for rising 6th and 7th graders. The camps are carried out by NAAOP staff and Native teachers who we hire for the summer. All folks have a few days at the beginning of the Summer to train together on the lessons and activities to be carried out. Then one person is assigned to introduce and be responsible for a particular activity, while everyone else pitches in as needed. The camp lessons build on and extend the concepts the students learn from the curriculum units in 5th and 6th grade. In 2023 NAAOP hopes to add an 8th grade Summer camp as well that has an emphasis on robotics.

Each camp is one week, and we rented a local dormitory near Lowell for sleeping and food service. The camps involved activities such as making a large replica of the surface of Mars or Venus, touring the ICE Lab at Northern Arizona University (NAU) used by Lowell astronomers to study the spectral signature of ices that might be found in the outer solar system, studying the geology of the Grand Canyon, and night sky observing. W. L. Gore and Associates, a technology company in Flagstaff that makes medical devices, became involved in our Role Models Program and they came to the Summer camps for a several hour presentation on devices that they have developed and on how an engineering project works.

In the first Summer (before the collaboration with KUSD began) we discovered that some students cancelled because their parent(s) could not afford the expense and/or the time from work to bring them all the way to Flagstaff. In fact, one teacher drove the four students coming from her school to Flagstaff herself (a 3-hour drive) so that they could attend. So in our second Summer, we drove vans out to Kayenta so that check-in could take place in the KUSD parking lot and we returned the students there when camp ended. We also learned the first year that many students did not have and could not afford sleeping bags for the campout on the last night, so we provided those along with the pads and tents. For some students we also provided sheets, blankets, and pillows for the dorm.

Winter Camp. In January of the third school year we held our first Winter camp. These two-day on-line weekend camps focused on Navajo traditional stories that can only be told in the Winter. Little, Tallsalt, and Black were primarily responsible for the cultural content.

THE EVALUATION PROCESS

Description. NAAOP subcontracted with Just Perspectives, LLC, established by Executive Director Castagno, also Professor in the Department of Educational Leadership and Foundations at Northern Arizona University. Prior to the start of the program, Castagno designed online survey instruments for participating students, teachers, and Lowell staff. Due to time and budgetary constraints, program evaluation was limited to these stakeholder surveys. Students completed the same survey at the beginning and end of the program year. The online student surveys were submitted directly to Castagno, and the only identifying information was grade level and gender. The student data were collated by grade level and analyzed for changes as a group over time.

The goal of the program is to help teachers increase their students' interest in STEM and STEM careers, so the purpose of the surveys was to assess the students' level of interest in STEM, including the extent to which that interest evolved while in the program. The student survey included Likert-type questions, as well as a question asking students to note the types of careers they were interested in pursuing. For example, one question on the student survey was "I would like to have a career or job in science" (1=Strongly Disagree to 5=Strongly Agree). Other questions were about astronomy, Native astronomy, technology, meeting Native STEM professionals, importance of science, and importance of STEM learning to their family, but all questions were chosen to elicit the student's degree of interest. The Summer camp surveys also included a career interest indicator.

In addition to the student surveys, Castagno solicited feedback through online surveys from Lowell Observatory staff and KUSD teachers who had participated in the program. The purpose of these surveys was to ascertain staff perceptions of student interest and engagement, as well as staff feedback on program successes and areas for improvement. The staff surveys included open-ended questions for staff to share narrative thoughts about the program. In addition to these surveys, the evaluation also included 16 program impact vignettes collected from teachers and Lowell staff. The quantitative survey data were analyzed using basic descriptive statistics, and the qualitative data (open-ended survey responses, and program impact vignettes) were analyzed through open coding.

NAAOP applied to the Navajo Nation Human Research Review Board (Navajo IRB; NNR-18.316) in 2018 for permission to carry out this research on the impact of the program on the interest of KUSD students in STEM. We received final approval of our Informed Consent Forms on January 23, 2019, and sent them home with students in our classrooms to be signed by their parents. We sent out additional forms to new students in Y2. Only students whose parents had signed these forms were allowed to fill out the online surveys.

COVID-19. The pandemic caused by COVID-19 had major consequences to the KUSD schools, students, and of course our project. Lowell Observatory shut down on March 13, 2020, the same day that one of the 6th grade classes left for home at the end of their field trip, and the schools closed about a week later. At that point, most of the Y2 partnerships had completed the curriculum units and three of the classes had taken their field trips. The rest of the field trips and what was to have been a community-wide star party were cancelled. The end-of-year student survey was never completed for Y2.

KUSD schools were virtual for all of Y3. NAAOP held training workshops for the new teachers online in September and October, and worked out what activities the students could do at home and what needed to be done as demonstrations. NAAOP assembled packets of materials for students (about 400), and mailed these to KES and KMS to hand out to their students. During the school year, NAAOP's Lowell partners would periodically attend the teacher's zoom session and lead discussions, activities, and demonstrations. Typically only about half of the enrolled students in a class attended and most were silent rectangles. Access to fast and reliable internet connections was a major barrier for many Navajo families. Clearly this was a challenging time for everyone.

Because of all that was going on related to KUSD pivoting to online instruction, the students we worked with in the first two years were distributed throughout the KMS classrooms in Y3. However, only students whose parents had signed the Informed Consent Forms were allowed to complete the surveys. Therefore, NAAOP shared the link for the student surveys with the teachers along with a list of students who were allowed to fill them out. They then shared the link with those students who were in their classrooms, but the response rate was low.

Summer camps in both 2020 and 2021 were also online. Again, NAAOP sent students packets of materials, notebooks, and Book Club books so that they could carry out activities at home together online.

EVALUATION RESULTS

At the end of Y1, Castagno compared the survey results from the beginning of the school year to the responses at the end of the school year and noted growth in the average responses on most items, which suggests a positive impact of the program on students overall. The pre-post comparison was tentative, however, because the pre-program survey had over 200 responses and the post-program survey had just under 100 responses. Unfortunately, for Y2 we only had student surveys at the beginning of the school year, and the number of responses in Y3 was low because of the consequences of COVID-19 (N=38 for the pre-program survey, and N=27 for the post-program survey). A full discussion of analysis of the survey results will be presented elsewhere. However, here we quote the final assessment:

> *Despite the limited data that were collected throughout the past three years, we still get a sense of the incredible potential of the NAAOP's new program model, the 4th-8th grade curriculum, and the Summer camp offerings….The NAAOP program, and the partnership with Kayenta specifically, continues to have significant potential for positively impacting teachers and students in Indigenous communities.*

Some promising quantitative results are as follows. The average response to the question "I would like to have a career or job in science" at the beginning of the 2018-19 school year (Year 1) was 3.52 with a standard deviation of 1.21 and at the end of the school year the average response was 3.75 with a standard deviation of 1.20. Another question was "In my culture, learning about science is valued." The pre- response average was 3.56 with a standard deviation of 1.12 and post-response average was 3.99 with a standard deviation of 1.14. In 2019 5 students in the two Summer camps indicated that they were interested in becoming astronomers at the beginning of the camps and 11 indicated interest in this career at the end. In both the student school year surveys and the Summer camp career interests, the area that showed the strongest improvement was engineering.

Teachers considered the connections students made between the curriculum and their culture. Greyeyes reflected on the collaboration with her 4th grade classes, "The students loved it. They looked forward with anticipation to the visit of the astronomer(s). I truly think it helped students become more aware of their natural environment and the changes taking place. It was great that they got to see through the lens of a scientist and had an opportunity to explore and do experiments with him/her. It was often expressed by the astronomer(s) to students that they can apply their curiosity in the field of science as students (now is where it begins) and [as] a potential/future scientist."

Little made the following observation about a student in the 6th grade class that she worked with, "A student was able to relate the Book Club book *Children of Time* to the curriculum and to her life. She demonstrated a clear understanding of climate change and the importance of energy flow to her own life. She figured out on her own that too much heat in the oceans was bad because there are animals in the ocean that depend on very cold water. She was also one of the students who, at the beginning, avoided raising her hand or talking because she was not confident. However, after a while, she began shouting out the answer and argued with me over global issues and issues on the Navajo Nation. She told me that science was not her favorite subject and that her grandpa had made her participate in the NAAOP program. But now she is glad that he made her participate because she loves science."

Pipe noticed the following from the 4th grade class field trip to Monument Valley, “One student was able to express how the wind was calm towards the canyon walls and that the measurement would be higher on the anemometer on the flats between the canyons, in addition, that it was why the dust devils were more active and consistent at the end of the canyon wall than right by it towards the center of the wall.”

DISCUSSION

Sharing the Curriculum with Others. While the cultural and local connections in the curriculum units that we constructed for KUSD were Navajo-specific, the academic part of the units can stand-alone. Furthermore, we see the opportunity for teachers anywhere to make their own local connections. Thus, we intend to share these units on the Lowell Observatory website so that teachers anywhere can use them. The lesson plans for each unit are very detailed, but NAAOP is currently preparing accompanying materials to help teachers implement the units. We are striving to have them online in 2023.

Whether you use these curriculum units, activities from *The Universe at Your Fingertips* (ASP, 1996) or other sources, or make up your own activities, partnerships between teachers and professional or amateur astronomers can be a lot of fun. The astronomer should remember that they are a guest in the classroom. They should be reliable, respectful, and always take their cues from the teacher. Work out with the teacher what activities to do, but they should be hands-on and age-appropriate—dramatic, messy ones with good “kid hooks” are favorites. If you are making a scale model of the solar system, for example, start off talking about model cars to get the concept of scale models across first. If the students are measuring something—say the size of a crater made by dropping a rock in flour, explain why they need to make multiple measurements and take an average. If you plan to leave supplies and materials with the teacher to use in later years, the teacher will need a lesson plan or description, detailed explanations, and labeled supplies, all collected together in some organized fashion. Materials and vocabulary lists are a great addition.

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Author Contributions

The NAAOP-KUSD collaboration was carried out with contributions of all authors. All authors have given approval to the final version of the manuscript.

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Lowell Observatory sits at the base of mountains sacred to tribes throughout the region. We honor their past, present, and future generations, who have lived here for millennia and will forever call this place home.

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ABBREVIATIONS

KMS: Kayenta Middle School; LO: Lowell Observatory; NAAOP: Native American Astronomy Outreach Program; NAU: Northern Arizona University; PBL: Project Based Learning

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