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REVIEW ARTICLE

The promises of studying cultural archeoastronomy across the Pacific Basin as a new scholarly science education research agenda

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ABSTRACT

Cultural archeoastronomy provides a unique intersection of scholarly study for science education scholars interested in the nexus of science, society, and culture. The study of archeoastronomy as a discipline combines astronomy, anthropology, archeology, celestial navigation, storytelling, navigational hula, and education. As such, it holds great potential as a naturally captivating hook for improving science education teaching efforts, particularly for place-based students who live in regions where sky stories have had tremendously strong influence on the local culture. This perspective calls for discipline-based astronomy education researchers to better understand the interplay between cultural astronomy and effective Science, Technology, Engineering, and Mathematics (STEM) teaching of diverse students as an important tool for culturally responsive pedagogical approaches.

Key words: astronomy education research, discipline-based science education research, archeoastronomy, astronomy

INTRODUCTION

People naturally often ponder the big questions of humanity when they look upward into the mysterious night sky: Who are we as sentient living beings? What is our purpose in the vast cosmos? Where are we in the seemingly endless ocean of space and time? What was the initial source of our life energy leading to when will our arduous journey be complete? Although less common today than in the not-so-distant past, peoples across the globe who were more intimately connected with the regimented and predictable cycles of nature often looked to the sky for pathways leading to answering the big questions (Brosch, 2011; Ruggles, 2005). Fortunately, the precise nature of how different peoples respected and paid attention to, made predictions from carefully maintained records of, and paid devout reverence to the objects and predictable motions in the sky provide a surprisingly detailed and insightful window into the daily lives, beliefs, and values of cultural practices and cultures who have long since left our living human realm (Chauvin, 2000; Lomsdalen, 2013; Magli et al., 2019).

Considering this perspective, cultural archeoastronomy can readily serve as an intellectual vehicle to provide a proverbial time machine for scholars to ride back into the past and begin to glimpse how people lived their lives (Goodwin, 2017). As but a few of many possible illustrative examples, imagine that determining how accurate those who watched the sky could precisely predict sky events, such as eclipses, reveals insight into how mathematically advanced a society was (Ruggles, 2015; Slater, 2008). In much the same way, carefully listening to which ancient stories a community's elders take time to relate that are archived in the dot-to-dot star figures in the sky demonstrate which timeless stories define the values of a culture (Eriksson, 2019; Saletta, 2011). Even a description of which animals are memorialized in one's sky constellations tell the environmental biologist which animals lived in a particular region (Rappenglück,

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2013). Given the richness of these notions, one naturally wonders if these heavenly ideas can be harnessed into improving Science, Technology, Engineering, and Mathematics (STEM) education (Avilés, 2022)?

Given the specifics that could occur region to region, deciphering which names of stars visible from widely separated islands of the Pacific Basin share names provides a unique way to track the migration of sailors navigating the seemingly featureless ocean (Dinsa et al., 2023). Examples such as this demonstrates the power of cultural archeoastronomy to inform the once seemingly disparate studies of anthropologists, archeologists, linguists, architects, astronomers, historians, and sailors, among many others (Holbrook, 2012; Holton et al., 2015). Given the potential power of such an all-encompassing field of inquiry, let us consider a brief overview of the breadth of cultural archeoastronomy, framed in its potential for improving science education.

THE PROMISES OF CULTURAL ARCHEOASTRONOMY

The power of cultural archeoastronomy as both an academic field of study, an avenue for teaching STEM, and a method to better understand the nature of the human experience makes at least three promises to interdisciplinary scholars across the academic landscape. One promise is political in nature. Cultural archeoastronomy holds the power to bridge geographically separated cultures and provide explanatory power where few explanations for human motivations and values previously existed. Everyone on the planet lives beneath the same sky, and the stars hold the potential for cultural unification.

A second promise supports scientific research. Much of the study of contemporary astronomy is held hostage by the male-dominated European traditions that guide and constrain astronomy's work today. Moreover, cultural archeoastronomy promises to explain what influences which individuals select astronomy as a career pathway (Slater, 2010), and even geographically where astronomers are bold enough to build their modern facilities (Slater, 2014a; Slater, 2014b).

The third promise of cultural archeoastronomy points scholars to the future (Slater et al., 2015). As people of diverse cultures go about the process of educating their own youth in the nature and importance of the predictable positions of objects in the sky, cultural archeoastronomy provides new avenues for better educating students heretofore rarely considered by teachers educated in traditional ways (Slater & Slater, 2015). In this way, cultural archeoastronomy holds the promise for motivating teachers from across the globe to learn about different, and perhaps more successful ways to educate their youth on an enormous planet that is becoming smaller each day because of technical advances and evolutions in telecommunications and information systems (Marinez & Ortiz de Montellano, 1988) This is wholly consistent with ideas surrounding the rapid growth of discipline-based ethnomathematics (Furuto, 2014), particularly of the genre studied across the Pacific Basin (Furuto & Monkoski-Takamure, 2023).

First, we will define cultural archeoastronomy as a valuable scholarly field of inquiry. Then, highlighting the methods of cultural archeoastronomy, we describe the societal benefits of each of cultural archeoastronomy's promises. Finally, we conclude with a discussion of how first-steps results of cultural archeoastronomy experimental and theoretical efforts motivate scholars to allocate additional intellectual energy to the no longer nascent field of cultural archeoastronomy in the service of improving STEM education.

CIRCUMSCRIBING A DEFINITION OF CULTURAL ARCHEOASTRONOMY

Before contemplating these proposed promises of cultural archeoastronomy, one would be well advised to establish a definition of the subject. Many disciplines across the landscape of academia seem to defy all attempts at creating a ridged definition. At the same time, for a broad field of study to be labeled as a respected scholarly endeavor, its range and domain do need to be somewhat circumscribed. Accordingly, one might not be surprised that both the experimental and theoretical boundaries defining the reach of cultural archeoastronomy studies are elusive. As a tentative first step toward defining cultural archeoastronomy, one might find it fruitful to consider the classic definitions its name's subcomponents, as shown in Figure 1, each in turn.

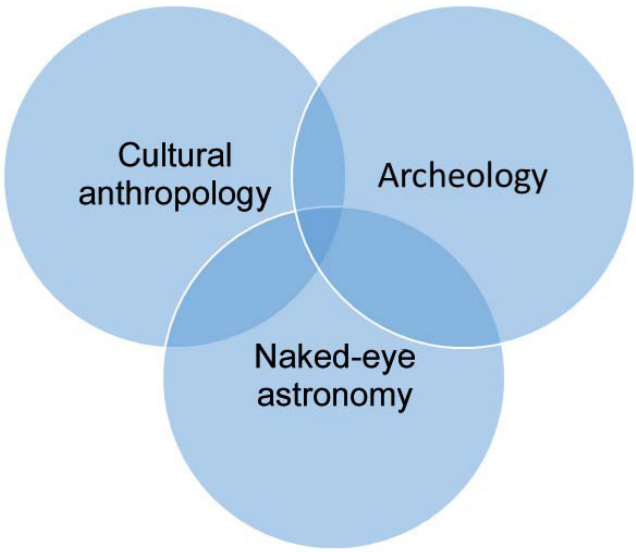

Figure 1. Major components of archeoastronomy.

One portion cultural anthropology

Whereas traditional anthropologists often describe themselves as scholars of humanity and its descriptive trimmings—art, spirituality, war making, kinship value, political power, and economies of trade are just a few examples—scholars of cultural anthropology focus specifically on cultural variations from one group to the next (Monaghan & Just, 2000). The dominant form of research method is extended duration, field-based participant observations. Data is collected in the form of observational field notes, interview transcripts, and participant surveys, among others. A guiding principle of cultural anthropology is to take precautions to avoid applying one's own cultural background and values to those of another group (Weakland, 1951). This research study approach is purposefully designed to avoid one's natural egocentric inclinations to believe that the researcher's own cultural arts are the most beautiful, his or her cultural values are the most virtuous, and that their own culturally-influenced beliefs the most truthful.

Curiously, novice anthropology students from the United States seem to be particularly subject to holding an unconscious bias of Western ethnocentrism (Pedelty, 2001). The reasons are many, but one is that individuals growing up and schooled in the United States spend considerable time learning about the cultural traditions of the United States' many immigrant cultures (Swanner, 2013). On one hand, many US-schooled students can readily identify that pizza originally comes from Italy, tacos come from Mexico, bratwurst and sauerkraut comes from Germany, and that cheese steak sandwiches come from Philadelphia. On the other hand, US-schooled students themselves seem to have great difficulty in identifying the cultural markers of their own culture including how one might allocate their free time on a non-school day, their sexual mores, characteristic musical styles, political inclinations, or identifiable commitments to spirituality. This is not dissimilar to the notion that "fish would probably be the last ones to discover the existence of water". Furthermore, such an egocentric phenomena has similarly been documented among novice history students-in-training, who tend toward interpreting historical documents and historical events according to the decidedly different cultural norms and values of today.

The reason that this is important to point out is similar pitfalls exist when first embarking on the study of cultural archeoastronomy. A common example of how unconscious predispositions are poised to interfere with a cultural archeoastronomy study is that of expecting astronomical alignments to occur among physical objects on Earth (Fierro, 2005). After all, one might naturally reason that if the ancient construction of Stonehenge is purposefully aligned astronomically, then one also might also naturally expect purposeful astronomical alignments to exist in the constructions of the ancient Nazca Line geoglyphs located in the Nazca Desert in southern Peru (they are not astronomically aligned) or the specific orientation of all sacred, navigational Heau temples in Hawai'i (some are aligned toward other Polynesian islands, rather than astronomically). A hypothetical example of airport runways that coincidentally match with particularly important star positions is shown in Figure 2. The cautionary tale here is that it is natural and desirable for scholars to aggressively look for potentially purposeful astronomical architecture, but it is surprisingly easy to mistakenly find alignments that are not actually there.

A perhaps unexpected but vitally critical tool of cultural anthropology are the perspectives and lessons learned from the field of linguistics. Formally, academic linguistics is usually described as the study of language and its structure. For the purposes of cultural archeoastronomy, the perspectives and methods of linguistics are critical for uncovering cultural values, even those that are not widely known to its community of users (Holbrook, 2012).

Consider for example the words of European languages defining the cardinal directions. The origins of the word North can be traced back to mean be the cardinal direction to the left-side when one is facing the rising of the morning sun. For ancient European merchants traveling to the East, establishing the cardinal direction of East would have been critical. Setting ones directional navigation across the desert would have best been done each morning by orienting oneself toward the rising sun. For an eastbound trader, the direction North would quite literally have been on one's left hand and the rising sun would have been a welcome apparition in the sky for navigating the nearly featureless deserts (Huth, 2013).

Although linguists traditionally associate the maritime words of starboard and port to functions occurring at specific positions on ancient ships, one might also speculate that for ancient merchant ships sailing eastward into the Mediterranean, the guiding North Star appears on the right—starboard—side of a ship and conversely, when returning westward back to its home port, the guiding

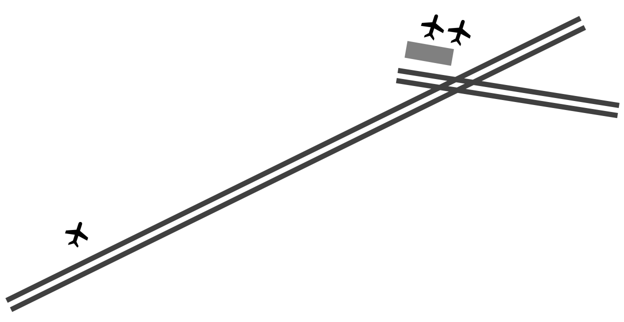

Figure 2. Runway directions match star risings. Runways at an airport, apparently "purposefully aligned" with the direction of winter solstice sun's horizon setting point at 240° and the rising point of Spica at 104°.

North Star appears on the left—port—side of the ship.

Halfway around the globe, consider the navigational needs of ocean-going Polynesian wayfinders. Although the empty ocean is nearly as featureless as deserts are, Polynesians most often use the stars, rather than the sun, to set calibrate cardinal directions. When facing West toward the disappearing sun, North is the direction off of one's right hand. When linguists look at Hawaiian language, they see that the Hawaiian words for North and for right-side are the same—ākau. As further evidence, the word for left-side is the same as South in Hawaiian—hema.

The bottom line here is that linguistic analysis of words reveal tremendous insight about cultures and the critically important nature of objects in the sky. Whereas European traders trying to navigate East through the desert paid close attention to the rising sun, and that is captured in language. In stark contrast, the Polynesian wayfinders trying to navigate between widely separated islands paid close attention to the starlit sky revealed by the setting sun, and this too is captured in their language (Goodwin, 2018). Because cultural archeoastronomers want to better understand a society's relationship to the sky, the discipline of linguistics applied in this way provides powerfully fruitful insight.

One portion archeology

The subtle and not-so-subtle differences between anthropology and archeology have been long debated by academics. For our purposes of developing a working and pragmatic definition of cultural archeoastronomy, the field of archeology can be thought of as the study of the how human societies lived by looking at the physical remains they have left behind.

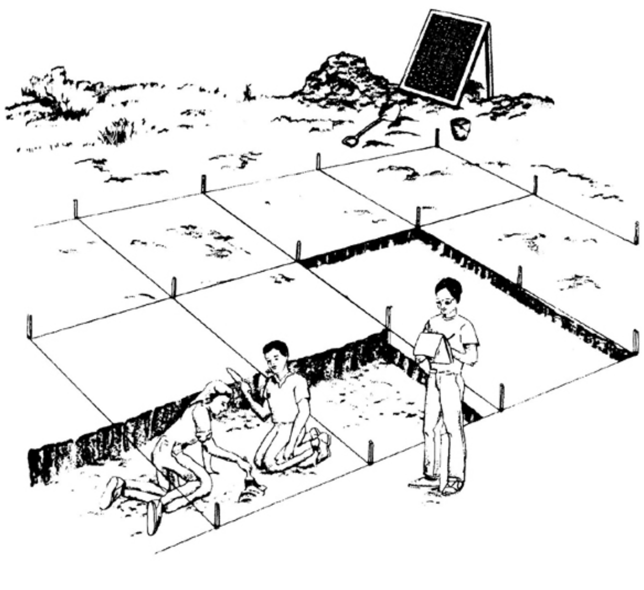

Figure 3. An archaeological dig site. Adapted with permission from Intrigue of the Past, LEARN NC (http://www.learnnc.org/Lp/editions/intrigue/1004).

The techniques traditional archeologists use to conduct their scientific inquiries usually involve surveying, excavating, and comparative, inferential studies of similar sites, as illustrated in Figure 3. Above all, determining the age of construction and duration of inhabitance are the fundamental questions driving archeologists (Glendinning, 2005). Absolute ages are determined by carefully removing samples from a site and taking them to laboratory and subjecting those samples to radioactive dating techniques. Radiocarbon dating works well for determining the age of organic materials up to about 50,000 years old, which would be useful if plant remains are found, such as those from a nearby refuse storage area. Potassium-argon dating is useful for dating fossilized hominid remains, such as those found in burial sites. For non-living, organic materials, thermoluminescence dating procedures can be used to date artifacts such as ceramics found at a temple.

Other strategies to determine the age of a site do not require rigorous, offsite chemical analysis, but still require meticulous recording of the precise position and orientation in which artifacts are found. Careful analysis of carvings, inscriptions, dated coins, and even historical manuscripts provide clear indications of how long ago a site was inhabited and over what period. Even looking at the style of stone tools used and correlating those tool designs to other nearby locations with known ages gives archeologists insights into how ancient a site is.

Fortunately, there are beautiful examples of archeological remains across the planet that are easily connected to the astronomical phenomena of the sky. With all the egocentric caveats described in the previous section freshly in mind, the most commonly recognized sites listed in the ever updating and evolving Wikipedia are: (1) The Newgrange passage tomb in the Republic of Ireland where Winter Solstice light shines along the central passageway. (2) Egypt's Giza Pyramids' construction and chamber alignments with ancient positions of stars. (3) The El Castillo temples and carefully aligned staircases of Chichen Itza in Mexico (Figure 4). (4) The sky-aligned Stonehenge complex of megaliths and earthworks in the Salisbury Plain of England. (5) The Neolithic chambered tomb on the Mainland of Orkney where the setting sun at midwinter shines down the entrance passage. (6) The Mayan city of Uxmal on Mexico's Yucatán Peninsula that have alignments with the rising positions of Venus. (7) Chaco Canyon of the North American Pueblo Indians hosting numerous lunar and solar markers and astronomically aligned roads. (8) The Lascaux Cave paintings in France incorporating prehistoric star charts.

One portion horizon-based naked-eye astronomy

If the close monitoring and the making of accurate predictions of the locations and motions of sky objects were highly valued by ancient peoples, it seems reasonable to assume that these efforts would be somehow memorialized in its architecture, writings, art, and language. As a result, a team of scientists probing a culture's characteristic should be at least somewhat familiar with the sky observations commonly made across a particular geographic location.

The tools and methods of horizon-based astronomers are not telescopes. Instead, the strategy for a meticulous sky watcher was to record the motions and positions of the sun, moon, planets, and stars with sufficient detail so that their positions could be consistently predicted with a high degree of accuracy (Dukes Jr, 1982). As an example, being the brightest and most object in the sky, the sun's cyclical motion would have been known to the most basic sky watchers. Although most people even today know that the sun rises in the East and sets in the West, the details of its motion often escape notice by most people today.

As it turns out, the sun doesn't always rise in precisely the same direction each day. The exact rising and setting positions of the sun gradually change from a point north of East to a point south of East over the course of six months, and then retraces its steps over the next six months. This annual progression takes about 365 ¼ days and defines a time period of a year.

In much the same way, the sun's noontime position in the sky also changes over the course of a year. In the months of December and January, the noontime sun is found nearer the Southern horizon. Six months later, in the months of June and July, the noontime sun hovers nearer the Northern horizon. This annual changing position of the noontime sun's precise location in the sky was well known to people more connected with the annual march of time than we are today, and served as a calendar.

The nightly motion of the stars across the sky were also carefully monitored by the ancients. Unless observed from Earth's North Pole or South Pole, most stars appear to rise from a predictable position along the Eastern horizon, move across the sky, and set in a corresponding direction along the Southern Horizon, as shown in Figures 5 and 6. The position and appearance of particular stars reveal at least two things to diligent sky watchers. For one, careful measurements of the maximum altitude above the horizon of reveal a traveler's latitude. For another, the appearance of particular stars are correlated with the calendar.

The precise rising and setting positions of the moon changes slowly over the decades, making this particular measurement difficult for cultural use. However, the changing monthly appearance of the moon does make an excellent tool to mark the passage of time. The moon's appearance changes of the course of each month (moon-th) from being a concave, slender crescent moon visible in the late afternoon and evening to being a fully, round moon visible at night, to then being a convex, slender crescent moon visible in the early morning hours before repeating its cycle, as illustrated in Figure 7.

Modern-day astronomy research is mostly concerned with understanding the physical processes governing the surfaces of orbiting planets, the interior mechanisms of shinning stars, and the gravitational influences of massive black holes and galactic collections of stars. Although ancients probably wondered why many sky objects shine or move across the heavens as they do, most ancient cultures spent more effort emphasizing a spiritual significance to what they saw happening in the sky and how these events that most dramatically impacted human affairs, such as the predictable occurrences of alternating rainy and dry seasons or the predictable apparitions of cyclical food sources. As a result, much of the arduously earned sky knowledge that was needed to be passed on

Figure 4. Illustration the sun-illuminated snake crawling up Mexico's Chichen Itza on the Summer Solstice. Source: Pamela posted on Discover Walks Blog (https://www.discoverwalks.com/blog/mexico-city/top-10-facts-about-chichen-itza/).

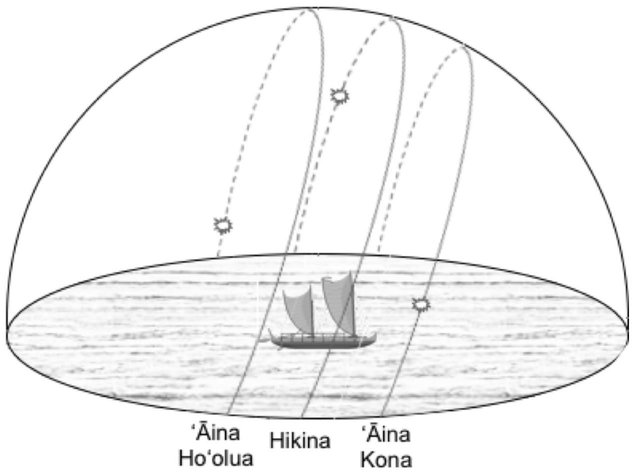

Figure 5. Illustration of the sun's changing pathway through the sky in June, September, and December.

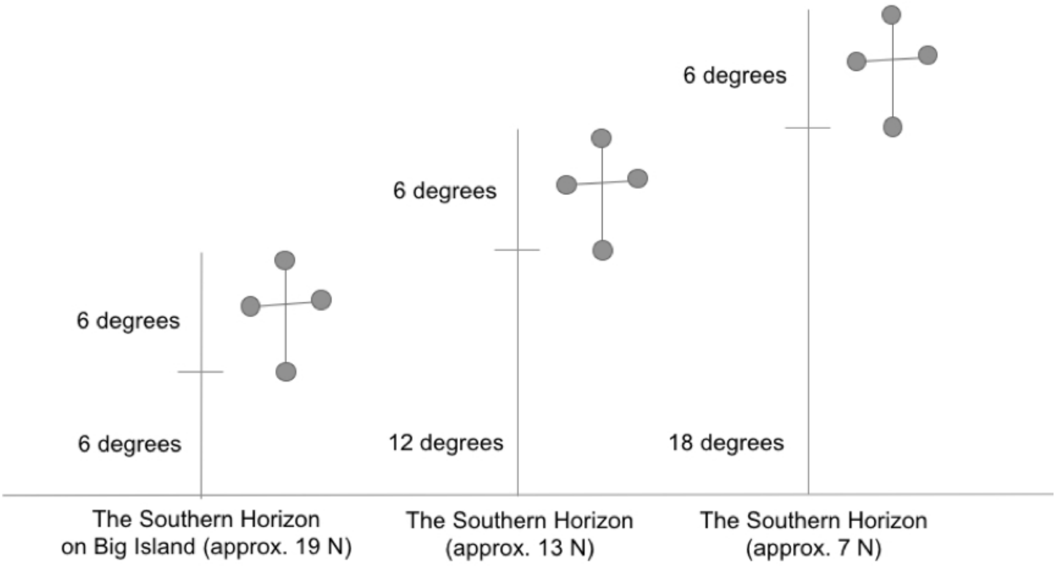

Figure 6. Illustration of how high above horizon of 'southern cross' appears depending on a traveler's latitude.

Figure 7. Illustration of moon's monthly changing appearance.

from generation to generation of wise men charged with watching the sky was encapsulated in songs, chants, writings, art, and architecture, that can best endure the devastatingly eroding passage of time.

CONSTRUCTING A DEFINITION OF CULTURAL ARCHEOASTRONOMY FOR THE PACIFIC BASIN

For several decades, scholar Clive Ruggles has passionately and tireless argued it is misleading to consider archeoastronomy to be the study of ancient astronomy. His argument is that modern astronomy is a scientific discipline, while archeoastronomy considers symbolically rich cultural interpretations of phenomena in the sky by other cultures (Dukes Jr, 1982). Taking his lead, and combining the rich traditions, methods, and knowledge of anthropology, linguistics, history, archeology, and horizon-based astronomy allows us to construct at least one working definition guiding this work. Cultural Archeoastronomy—also curiously spelled archeoastronomy in some parts of the world—is the methods and principles guiding the study of how cultures have in the past and now use and understand sky phenomena, how they use and used these phenomena to guide human events, and what role the sky plays in characterizing cultures. Such a definition conflates the tenants of what some might designate cultural astronomy, historical astronomy, and ethnoastronomy.

Scholars have aggressively argued elsewhere that cultural archeoastronomy studies leading up to today have been dominated by Western European traditions and Western European voices (López, 2019). As a community, we are convinced that our scholarly work would be better informed and more solidly robust if a wider diversity of scholarly voices influenced the work (Slater et al., 2011). Not only are there invested elders that come from non-academic traditions who could make cultural archeoastronomy better, there are many astronomers who know little of the techniques of historical document analysis, many linguists who know little of the changing patterns in the sky, and many art historians who know little of why sky phenomena might influence architecture.

Without trying to intentionally tread on the scholarly toes of others thusly infringing on their academic areas of expertise, this working definition unapologetically integrates the study of ancient cultures no longer with us with evolving cultures that are alive today. Such an approach enriches and expands the studies of cultural archeoastronomy rather than diminish or constrain them. Specifically, such a pragmatic definition purposefully does not limit the realm to ancient people no longer in existence because cultural archeoastronomy provides insight into thriving cultures that can be studied through this lens—such as what we are observing in real-time through a Hawaiian cultural Renaissance being driven by a return to modern-instrument-free navigation of ocean voyaging canoes, an activity in which bright navigational stars are being formally named at the very moment of this writing.

Although the majority of people readily conger images of Stonehenge, Chichen Itza, and the Big Horn Medicine wheel when thinking about ancient sky watchers engaged in their trade, the gigantic Pacific Basin (as shown in Figure 8) holds surprisingly rich resources and opportunities for cultural archeoastronomy studies. The Pacific Basin is more than just the islands of Hawai'i or Rapa Nui (Easter Island), or even only includes the nearly countless islands dotting the Pacific Ocean. The Pacific Basin includes cultures representing all the coastlines that outline the Pacific: the western Americas, Australia and New Zealand, Eastern Asia, the Aleutian Islands, and Alaska. This is a tremendously diverse group of cultures flourishing in highly diverse climates. Yet, over time, these peoples have interacted, shared knowledge and resources, and even shared their knowledge of sky phenomena. This sharing of sky phenomena is important not just because what one can observe varies tremendously across the region, but because the sky reaching from horizon to horizon is what brings people and cultures together. Capitalizing on this natural inclination provides an opportunity for something novel among STEM education circles.

THE PROMISES OF CULTURAL ARCHEOASTRONOMY

The promise of cultural archeoastronomy to bridge cultures

As voyagers moved from island to island, connecting isolated people-to-people across the enormous Pacific, they brought their culture with them. Chiefs would bring political knowledge to share, medics would bring new techniques for combating illnesses to share, cooks would bring food preparation and preservation knowledge to share, craftsman would bring their knowledge of constructing sea-worthy canoes and strong sails to share, and, because every sailing crew would necessarily include a navigator, the wayfinders would share their strategies for moving from one island to the next. Because sky knowledge

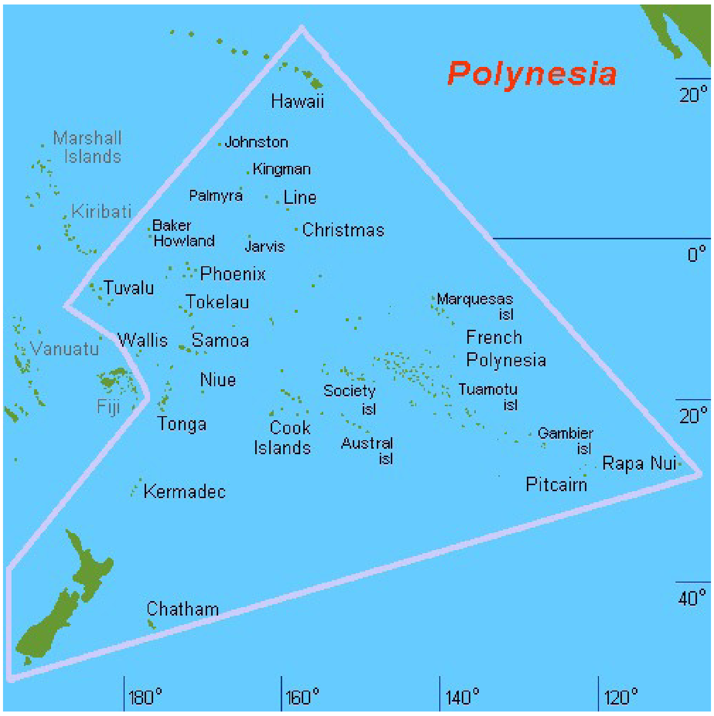

Figure 8. Illustration of the Pacific Basin. Source: Hobe/Holger Behr, Public domain, *via* Wikimedia Commons.

is so intimately tied to most navigational wayfinding techniques, navigators needed to share their names for sky objects so they could communicate with other navigators. Over time, names of sky objects evolved and migrated across the Pacific, meshing and integrating with other languages in sometimes obvious, and sometimes not so obvious ways (Johnson et al., 2015).

Across much of the Pacific Basin, each of the 30 apparitions of the moon has its own name, which are shown in Figure 9 (Bryan et al., 2015). This naming convention differs markedly from a European tradition of only a few generalized names for the moon—new; waxing or waning; crescent, quarter, or gibbous; and full. Upon inspection, one can easily see how these names of the moon are similar across widely separated islands, by people who would rarely come in contact with one another (Figure 9).

Although sharing specific names for the varying appearances of the moon might seem somewhat trivial in through the lens of today's modern culture, this was of tremendous importance in days of long past. Consider the nearly countless things one might share when meeting someone for the first time from an island (or planet) different from your own home. For one, you might naturally pick something you both share in common as a starting place for cultural exchange—in this case, the moon's appearance. Sky knowledge in particular represents a highly valuable thing to share, because sky knowledge is arduously developed

The Nights of the Moon

NIGHT	HAWAIIAN	MAORI	TAHITIAN	RAROTONGAN	MARQUESAN	MANGAREVAN
1.	Hilo	Whiro	Tirio, Teriere	'Iro	Ta-nui	Tu-nui
2.	Hoaka	Tirea	Hirohiti	Oata	Tu-hava	Hoata
3.	Kūkahi	Hoata	Hoata	Amiama	Hoata	Maheama-tahi
4.	Kūlua	Oue	Hami-ama-mua	Amiama-aka-oti	Mahea-ma-tahi	Maheama-rua
5.	Kūkolu	Okoro	Hami-ama-roto	Tamatea	Mahea-ma-vaveka	Maheama-toru
6.	Kūpau	Tamatea-akiri	Hami-ama-muri	Tamatea-aka-oti	Mahea-ma-hakapau	Maheama-riro
7.	'Olekūkahi (1st)	Tamatea-a-ngana	Ore-mua	Korekore	Koekoe-tahi	Korekore-tahi
8.	'Olekūlua	Tamatea-aio	Ore-muri	Korekore-aka-oti	Koekoe-vaveka	Korekore-rua
9.	'Olekūkolu	Tamatea-whakapau	Tamatea	O-Vari	Koekoe-hakapau	Korekore-toru
10.	'Olekūpau	Huna	Huna	'Una	Ai (Mahau)	Korekore-riro
11.	Huna	Ari-roa	Rapu, Ari	Maaru	Huna	Ari
12.	Mohalu	Mahwharu	Maharu	'Ua	Mahao	Huna
13.	Hua	Maurea	Hu'a	E-Atua	Hua ('Ua)	Maharu
14.	Akua	Atua-whakahaehae	Maitu	O-Tu	Atua	Hua
15.	Hoku (fullest)	Turu	Motu	Marangi	Hotu-nui	Etua
16.	Māhealani	Rakau-nui	Mara'i	Oruru	Hotu-maie	Hotu
17.	Kulu	Rakau-matohi	Tur'i, Turutea	Rakau	Tu'u	Maure
18.	Lā'aukūkahi	Tikirau	Ra'au-mua	Rakau-roto	Aniva (Akau)	Turu
19.	Lā'aukūlua	Oika	Ra'au-roto	Rakau-aka-oti	Matahi	Rakau
20.	Lā'aupau	Korekore	Ra'au-muri	Kore-kore	Kaau, Akau	Motohi
21.	'Olekūkahi	Korekore-tutua	Ore-mua	Korekore-roto	Koekoe-tahi	Korekore-tahi
22.	'Olekūlua (3rd)	Korekore-piri-ki-tangaroa	Ore-roto	Korekore-aka-oti	Koekoe-waena	Korekore-rua
23.	'Olekūpau	Tangaroa-a-mua	Ore-muri	Tangaroa	Koekoe-haapau	Korekore-toru
24.	Kāloakūkahi*	Tangaroa-a-roto	Ta'aroa-mua	Tangaroa-roto	Takaoa-tutahi	Korekore-riro
25.	Kāloakūlua*	Tangaroa-kiokio	Ta'aroa-roto	Tangaroa-aka-oti	Takaoa-vaveka	Vehi-tahi
26.	Kāloapau*	O-Tane	Ta'aroa-muri	O-Tane	Takaoa-hakapau	Vehi-rua
27.	Kāne	O-Rongo-nui	Tane	Rongo-nui	Puhiwa (Vehi)	Vehi-toru
28.	Lono	Mauri	Ro'o-nui	Mauri	Tane (Moui)	Vehi-riro
29.	Mauli	O-Mutu	Ro'o-mauri	O-Mutu	Nu-nui	Tane
30.	Muku (NEW)	Mutuwhenua	Mutu, Mauri-mate	Otire-o-avaiki	Nu-mata	Mouri

[*Kaloa is shortened from Ka'aloa.]

Figure 9. Names of moon phases. Adapted with permission from Bryan et al. (2015).

over time and one's sky knowledge holds an elevated place in the hierarchy of most any culture's knowledge. In this way, sky knowledge—especially when encapsulated in easily transportable art, dance, and song—serves as a first step in cultural exchange. These issues stand at the core of culturally responsive pedagogical approaches to enculturating and teaching youth.

As a modern day example of tremendous importance to the people of the Pacific Basin in using sky knowledge to create cultural exchanges, consider the worldwide voyage of the double-hulled Hokule'a and Hikianalia ocean-going canoes. The cultural exchanges made possible by the construction and sailing of these traditional voyaging canoes over the last several decades is driving a Hawaiian cultural and voyaging renaissance with global reach. The last known living instrument-free master navigator of the Pacific was Mau Piailug, a Micronesian navigator from the Carolinian island of Satawal. Before his death in 2010, Mau Piailug charged five modern day Hawaiian navigators with keeping the wayfinding traditions and navigational knowledge alive: Chad Kalepa Baybayan, Milton "Shorty" Bertelmann, Bruce Blankenfeld, Chadd 'Onohi Paishon, and Charles Nainoa Thompson.

In keeping with that promise, together with apprentice navigators, the Hokule'a and its sister canoe Hikianalia embarked on a 3-year, 85-port, 26-country, 48,000 mile circum-navigational voyage around Earth, shown in Figure 10. The educational and diplomatic voyage driven by the notion of living under the same sky phenomena is known as "Malama Honua", which means "to care for our Earth". While voyagers on Hokule'a strictly use the stars, ocean current, winds, and birds as mapping points for navigation, accompanying sister canoe Hikianalia is outfitted with state of the art technology and satellite communication systems allowing crew-members to communicate with classrooms and the media and the world *via* live chats, videos, blog posts, and photographs, thereby expanding its reach.

These two examples—ancient migration of names for the moon's appearance and using sky navigation as a means of cultural exchange—demonstrate how understanding cultural archeoastronomy can serve as natural bridge across cultures. When coupled with the aforementioned academic inclination of cultural archeoastronomers to welcome people from across scholar fields as well as those individuals not traditionally steeped in formal academia, such as community elders, cultural archeoastronomy contains promises of cultural bridges and foundational aspects of teaching with culturally responsive pedagogies.

The promises of cultural archeoastronomy to enhance contemporary western astronomy

Modern astronomy as practiced in the Western, European tradition requires the construction and use of massive telescopes to collect the faintest amounts of starlight from unimaginably distant objects. For both traditional and pragmatic considerations, modern telescope facilities are often constructed on remote mountain tops, far from blinding city street lights, and high above intervening clouds. Such astronomical observatories often represent a tremendous financial investment on the part of governments and institutions. Perhaps more importantly

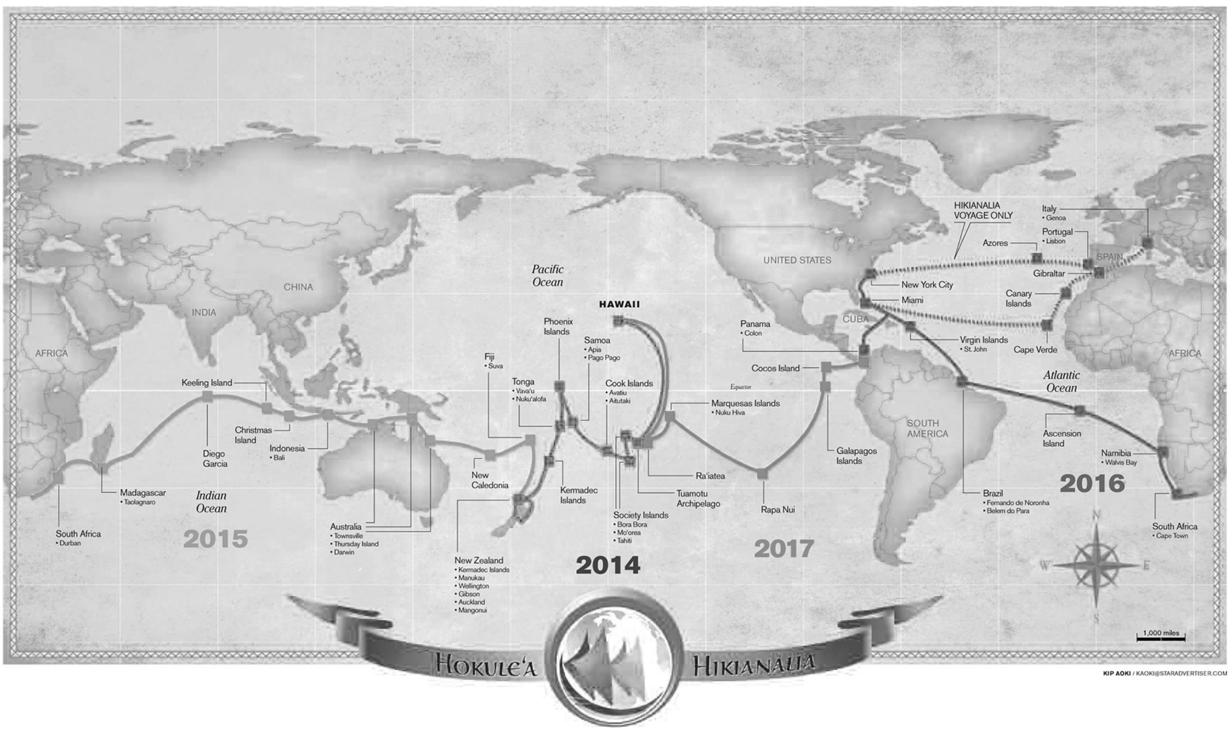

Figure 10. Worldwide voyage of Hokule'a. Adapted with permission from Honolulu Star-Advertiser.

than the money involved, the decades of time invested by individuals in designing and building astronomical observatories often represents entire career lifetimes of dedicated and tireless work in bringing these telescope projects to fruition.

At the same time, a seemingly remote mountain summit reaching far above the surrounding people can represent a tremendously valuable cultural resource. For some, a towering mountain can serve as a symbol that represents an entire culture. Appropriating a physical resource as cultural identity is far from being unreasonable even in contemporary society. For example, Mt Fuji as an iconic symbol of Japan, Mt Rushmore and the Grand Canyon in the United States, Iguaçu Falls connecting Brazil and Argentina, the Eiffel Tower in Paris, and the Pyramids of Giza in Egypt, as well as countless places given spiritual reverence honoring our ancestors such as memorials and cemeteries. From this perspective, it seems reasonable that peoples living nearby might naturally adopt a mountain summit as an important characteristic of their culture.

In the domain of contemporary astronomy, at least two grand mountains serving as locations for astronomical telescope observatories are places of intense cultural conflict between local people and modern scientists. The loudest in current times being the continued construction of facilities near the summit of Maunakea on the Big Island of Hawai'i in the center of the Pacific Basin. Although telescope facilities have been in place on this mountain for many decades, the most recent conflicts have made international news headlines because the proposed construction of one of the world's largest telescopes—the Thirty Meter Telescope (TMT). Another representative cultural conflict between local inhabitants and professional scientists is that surrounding astronomical facilities on Kitt Peak near the Tohono O'odham Nation and that of nearby Mt Graham near the Apache Tribes in the Southwestern United States. It is worth noting that astronomers from the University of Arizona led the push for rapid astronomical development of all three of these mountain settings.

For our present purposes considering the promises of cultural archeoastronomy, people across the spectrum of opinions on these issues have appropriated the results and emphases of cultural archeoastronomy to provide intellectual warrant for their various positions. In Hawaii, various advocates have noted that Hawaiian Kingdom King Kalakaua reportedly viewed Venus' transit of the sun using a small telescope constructed in Honolulu in 1874 and soon thereafter visited Lick Observatory in the United States and felt strongly that such a fine scientific facility should also be constructed within his kingdom. Moreover, the ancient seagoing Polynesian wayfinders who navigated using the stars are sometimes referred to as the original Hawaiian astronomers.

The natural observation is that cultural archeoastronomy can provide a critical bridge between differing factions (Bailey & Slater, 2005). If one can tie modern day human events to critical knowledge and motivations of cultures in the past, this provides a bridge of common interest. In these cases, the combination of ancient sky knowledge use connected with modern day astronomy holds great promise to serve as such a peaceful bridge between cultures.

At the same time, modern day astronomy as a scientific career field suffers greatly from a lack of diversity in who decides to pursue astronomy as a career. In comparison with other scientific fields across the globe, astronomy is comparatively more male, Caucasian, and traditionally European in methodological approach. In the past several decades, there are no more than a mere handful of Hawaiians who have completed even undergraduate degrees in astronomy, let alone graduate degrees that go on to pursue careers as astronomers. This is despite considerable effort aimed at changing this situation. Unquestionably, Native American Indians and Pacific Islanders—both who have a rich cultural heritage tied to sky knowledge—expressly do not decide to become professional astronomers even when given the financial resources and encouragement to do so. This seems like a situation begging for a fulfilled promise of cultural archeoastronomy to bring brilliant youth who come from a rich ancestral line steeped in the sharing of sky knowledge that guided human events to become modern day sky watchers as professional astronomers. Professional astronomy as a field of inquiry would itself benefit greatly from an increased diversity in backgrounds, viewpoints, expertise, and values of those who serve as the next generation of astronomers.

The promise of cultural archeoastronomy for improving education

Pioneering American Educator Horace Mann is often credited with proposing that education is the great equalizer. More accurately, he is quoted in 1848 as saying, "Education then, beyond all other devices of human origin, is a great equalizer of the conditions of men—the balance wheel of the social machinery". Although this sentiment has probably been advocated by many thought leaders throughout time, one wonders if the results of cultural archeoastronomy can partially fulfill his promise for bringing seemingly diverse peoples from different cultures to a more morally level sense of equality than exists worldwide today. For this writing, the question is does cultural archeoastronomy have a promise to keep to the education of school children.

Across much of Western civilization, there is a consistent misunderstanding among school children about the appearance of sky objects. It has been well established by discipline-based astronomy education researchers that the majority of Western-schooled students can not accurately illustrate the sun's changing pathway through the sky during the year, cannot adequately describe the reasons many places on Earth experience seasonal changes, and cannot successfully describe the cyclical changing appearance of the moon (Bailey & Slater, 2005). With specific reference to understanding the phases of the moon, few students report that the moon can be seen during the day.

It is curious that this prevalent widespread misconception across Western civilization that the moon is not visible during the day is not prevalent across the interior of the Pacific Basin. Specifically, this misconception is not observed in children educated in schools that emphasize Hawaiian cultural values. This is a curious education research result that can only be adequately explained using the lens of cultural archeoastronomy.

In most western schools, students generally learn a few phases of the moon as being, in order: new, waxing crescent, 1st quarter, waxing gibbous, full then waning gibbous, 3rd quarter, and waning crescent. These names have little if any cultural meaning to today's school students, and are subject to rapid loss from memory after being tested in schools.

Traditionally, Hawaiians paid great attention to the nightly changing appearance of the moon, and used it to mark the passage of time. With so many tasks to be done— fishing, planting, warring, worshiping—the moon's shape provided structure and a measured pace to daily living. For example, fishing for certain types of fish or in particular locations was only allowed during specific moon phases to prevent overfishing. Other phases signaled when high tides occur at sunrise, making canoe launching easier or when fishing efforts should momentarily pause and regular preventative maintenance could be done repairing fishing nets.

In stark contrast to the schooling of most Western school students, as alluded to earlier, school students throughout Polynesia, and specifically in Hawaii, often learn all 30 names, illustrated in Figure 11, for the nightly phases of the moon. Thirty is indeed a large number. To make the

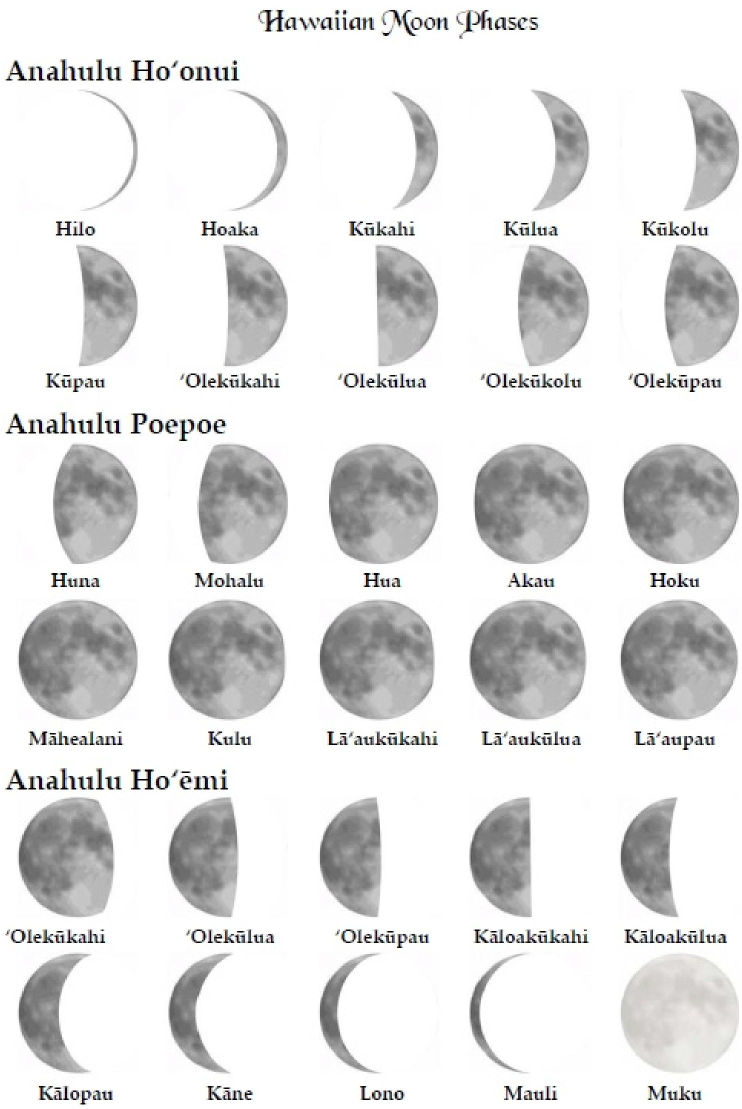

Figure 11. Hawaiian moon phase names. Adapted with permission from Bryan et al. (2015).

task easier, Hawaiian moon phase names are broken up into three 10-night periods categories: moons seen in the afternoon and evening; moons that illuminate the night; and moons seen in the morning. All 30 moon phase names have traditionally been memorized by all Hawaiian children and serve as a part of Hawaiian cultural life and education. Adding emphasis to the importance of this sky knowledge, a noted Hawaiian cultural proverb alludes to a person who is ignorant as being, "like a child who has not yet learned the phases of the moon".

The bottom line here is that cultural archeoastronomy holds a promise for designing highly effective STEM educational learning experiences. In this simple example, where many others exist, it seems natural to conclude that if Western-schools adopted a three-phase approach to teaching moon phases (that is tied directly to when different moons can be seen) instead of a Western-based four-quarters approach (that is disconnected from students' observations of the sky), then education might be more successful. By comparing sky knowledge teaching techniques from one culture to the next, the end result could lead to the development of highly successful educational experiences, bringing the promise of a more equalized global society to fruition for our children.

DISCUSSION AND CONCLUSION

Given that there are many facts and concepts conventional school children struggle with learning (Adams & Slater, 2000), and given that there are many astronomy ideas that schools are required to teach children across the planet (Adams & Slater, 2000; Slater, 2000; Schleigh et al., 2015), one naturally wonders if couching astronomy as the intersection of science, technology, and culture might be more successful at providing an innovative and robust educational learning experience. This motivates a new science education research agenda: combining the mysteries of learning about space, the wonder of ancient civilizations, and the dynamic nature of culture enhance student achievement, affect, and motivation toward joining the STEM career pipeline. And, more than just will students learn more STEM concepts, one wonders if being more sensitive to cultural issues will increase all students interest in learning. At the same time, there are few existing curriculum materials for teachers wanting to leverage cultural archeoastronomy, which motivates, in turn, the systematic study of what sorts of curriculum and instructional approaches will work best. Furthermore, it is unclear what misconceptions teachers will need to address within their students when combining these seemingly disparate areas. In short, a robust research science education research agenda seems worthy of consideration.

Academically, cultural archeoastronomy is well established as a valuable scientific endeavor of inquiry. Predominantly, the field provides unique insights into how cultures in the past understood sky phenomena and how they used sky phenomena to guide and interpret human. At the same time, the field is mostly dominated by traditional academic voices steeped in a long history of Western scientific traditions. As an evolving field of inquiry, cultural archeoastronomy will be greatly enhanced by expanding the number of voices speaking, particularly those not from western traditions. An increased diversity of participants who have voice can only serve to make the results of cultural archeoastronomy more robust and greatly expand the research questions the field is willing to value.

The most important findings of this theoretical work pointing toward an action-oriebted science education research agenda are these: First, the intersection among naked-eye astronomy, archeology, and cultural anthropology contains all the components needed for STEM educators to develop and study fascinating learning tasks. Second, the richness of the Pacific Basin cultures—in connection with their cultural revolution stoked by astronomy and celestial navigation—are too important for science educators to ignore. Finally, the culturally rich domain of archeoastronomy, when paired with the naturally captivating wonder of the night sky, provides a fresh opportunity for STEM educators to look at how STEM learning can be enhanced by making tight ties to cultural issues and linguistic issues.

Not only will expanding the diversity of voices influencing cultural archeoastronomy improve that field's own productivity, such an expansion has the possibility to fulfil global promises cultural astronomy can make for a strong avenue for educational interventions. For one, cultural archeoastronomy holds unique powers to bridge geographically separated cultures under a single sky. For another, an expanded view of cultural archeoastronomy can improve modern astronomy by enhancing who is doing astronomy and how it can be done respectfully. In the end, a cultural archeoastronomy framework is well poised to provide an innovative pathway for STEM educational efforts, and worthy of mounting a science education agenda to explore systematically.

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