



“We constantly have to navigate”: Indigenous students’ and professionals’ strategies for navigating ethical conflicts in STEM

Angelina E. Castagno¹ · Jani C. Ingram¹ · Ricky Camplain¹ · Davona Blackhorse¹

Received: 5 May 2021 / Accepted: 15 September 2021
© The Author(s) 2022

Abstract

This paper reports on a research project that explored ethical, cultural, and/or spiritual conflicts and the various strategies used to navigate the conflicts among over 400 Indigenous students and professionals in science, technology, engineering, mathematics, and medicine [Our initial project was conceptualized as including STEM fields (not including the final M for medicine/health-related fields). However, our work included survey respondents and interviewees in medicine/health-related fields, so our subsequent analysis and discussion uses the more inclusive acronym of STEMM.] (STEMM) fields. These navigational strategies include teaching others and leveraging their support, engaging in ceremonial practices to provide protection and correction when needed, being in the right mindset and/or acting in the right ways, and—for some—changing pathways altogether. By centering Indigenous students’ and professionals’ voices and experiences, we learn how intentional, complex, and thoughtful their strategies must be.

Keywords Indigenous · Native science · Ethical conflicts · Spirituality · Epistemology

Nahat’á Saad Hast’eelyaa

Bitsį́ Yishtłizhiih éí hajooba’ íínizino Diné da’nłts’áádee deiíkááhii k’é bijinígo naanish dóó ółta’ haz’áagi bee hóldzil haleeh nidi bee haz’áanii éí Bilagáanaa bizaad bee hadadilyaa azéé’ ííł’íni dóó nida’alkaahí béesh t’áábí nitsékeesí da bee nida’anishó Hoghan bił nahaz’ágo tó hadaazlı́o, atsinilt’ish bee da’diltł’o bíla’ ashdlá’ii diishjį́di STEMM wolyéoo yee da’ahótą’ – science, technology, engineering, mathematics and medicine éí wóda’go ółta bił nahaz’á Bitsį́ Yishtłizhiih k’ad t’óó ahayoi atah binaanish silį́’. Wóda’go ółta’ nahaz’áagóó na’alkaah naaltsoos naaznilo bee nida’nitin dóó baa yáti’ éí STEMM bóhónéedzáo áyósin. STEMM éí na’alkaah alááh binidii’a’o baa nitsáhákees áko Bitsį́ Yishtłizhii na’alkaah

The authors are grateful to Mr. Malcolm D. Benally for assisting Davona Blackhorse with the Diné executive summary.

✉ Angelina E. Castagno
angelina.castagno@nau.edu

¹ Northern Arizona University, P.O. Box 5774, Flagstaff, AZ 86011, USA

niha'álchíní haadeit'éégo honiit'ahoda éí baanáhát'íggo baa yáti'o bá hoo'aah díí south-western United States, e'e'áahgi kéyah ashdladiin hahoodzoh biyi' kot'éégo nihit nahaz'á. Na'alkaah naanish ályaa éí díídi neeznádiin naaltsoos na'idíkid hadeediilaa áádóó tádiin bíla' ashdlá'ii nidabidéékid. Díí na'idíkido na'alkaah ályaaígí éí hazhó'ó néel'íí'o bee eehoozin: bitsi' yishtlizhii da'ólta'íí áádóó k'ad nidaalnishíí éí Bitsi Yishtlizhii bibee'ó'ool'íí siláagi áádóó dadílingo baa nitsehakeesii áádóó doo ádaal'íinii éí k'ad kot'áo STEMM yaa yádaalti'o bee haz'áanii bik'ehó hasht'eelnééh baa yáti'. STEMM na'alkaah biniyé na'idíkid alyáá éí bíla' ashdlá'ii nahasdzáán bich'í kónályaago naalkaah éí doo bíl yá'ádaat'ééhda, áádóó bíla'ashdlá'ii bits'íis nanise' bitl'óól naalkaahdó bahasti'o dílzin, áádóó bitsi' yishtlizhii bikéyah bikáá'óó álido' hane' bidadééti', keyah lahgoó éí hodiyingo nahaz'á baa hasti' éí biniinaa ts'ídá bíla ashdlá'ii be'oodlā' siláagi baa saad hólq nahalin, áko bilagáanaa bibeehaz'áanii hazho'ó nánél'íího éí bitsi' yishtlizhii da'ólta'íí dóo nidaalnishíí éí díí naalkaah bee 'ééhoozin. Áko wódaho ólta'I éí díígi ádahoot'éégo hait'éégo éí baa yati' dóo naanish ádoolnifíí t'áá naniit'ah. Áko wódahgo ólta' bíl nahaz'áagóó altsé t'óó baa yá'áti' bíla' ashdlá'íí áá'át'éégo be'í'ool'íí nidaazti'íí bee na'nitino éí binahjí' beehaz'áanii hast'édoolnifíí nídook'as, áádóó lahdoó éí nahaghá ádaalyaago éí t'áá saad bee haz'áanii t'áá altsó bik'ésti' bik'ehoi áhálnééh, doo hazho'ó baa nitséhaskéézo ahil nida'anish éí bééhózíni dooléél áádóó náás dah'náá'didooldaho baa nitséhakees dooleel.

Indigenous people navigate uniquely significant ethical, cultural, and spiritual tensions between standard practices, norms, and expectations in STEMM fields and their own cultural, spiritual, and epistemological commitments. Although there is a growing body of research on factors that contribute to the underrepresentation of Indigenous people in STEMM, there exists virtually no empirical research focused on the nature and potential impact of culturally, spiritually, and/or epistemologically informed ethical conflicts experienced by Indigenous students and professionals in STEMM pathways. This is curious because there is a rich body of conceptual literature on the distinct knowledge systems, epistemologies, and sciences engaged by Indigenous peoples. Our research complements and extends this work by investigating the specific nature and extent of the conflicts Indigenous students and professionals experience *in practice* along their STEMM pathways. As we describe below, this project has resulted in a large dataset, so we focus here solely on the strategies Indigenous students and professionals engage to navigate the ethical, cultural, and/or spiritual conflicts they experience in their coursework and job duties.

What do we know, and what more did we want to learn?

The body of work investigating challenges for Indigenous students and professionals in STEMM disciplines has mainly focused on the lack of available role models in these fields (Ingram 2009), differences in the way Indigenous people interact with each other and their surroundings (Bang and Medin 2010), and the absence of culturally responsive educational practices in schools serving Native youth (Castagno and Brayboy 2008). But there is virtually no empirical research that investigates whether, to what extent, and the nature of culturally significant ethical and spiritual taboos or how these issues may present very real conflicts with STEMM training and career expectations for Indigenous people (Williams and Shipley 2018). Caughtman (2013) points out that we have not adequately investigated the diverse backgrounds of cultural groups in STEMM or, more importantly, Indigenous

people's spiritual and/or religious relationships to the universe and how fundamental these relationships are to engaging in STEMM career paths. Many of us know from experience that some Indigenous people may consider certain standard practices in STEMM (i.e., viewing of an eclipse, working with human remains, designing infrastructure on sacred sites) as taboo or otherwise problematic, but we lack empirical research that confirms the anecdotes many of us have accumulated over the years. Further, the perceived non-acceptance of religion and spirituality within the scientific community accentuates cultural differences between Indigenous people and STEMM fields (Weldon 2007).

The first two authors came together around a shared interest in understanding the role ethical conflicts may play in Indigenous people's STEMM career pathways. Castagno is a White woman whose expertise is in Indigenous education, racism and educational equity, and educational anthropology. Ingram is a Navajo woman and analytical chemist whose expertise centers on environmental health issues on tribal lands caused by legacy hard rock mining and pesticide use. In her labs and student training programs, Ingram has experienced, first hand, concerns involving ethical issues in science and her Indigenous students' perspectives. For example, her lab utilizes standard reference materials to compare their analytical sample preparation to samples of interest in their research. One of the reference materials that has certified information on the elemental composition in biological material is a human lung material. A Navajo student working on a project that needed to compare his analytical chemical methods to a reference material informed Ingram that he could not work with the reference material because it came from a human subject. He said that if it were a requirement, it would be necessary for him to have a ceremony done after working with the material. However, it would be expensive and something he would prefer not to have to pursue. This is not an isolated experience, so our research explored the extent to which ethical conflicts such as this exist for Indigenous students and professionals in STEMM pathways, the nature of those conflicts, and the ways the conflicts are handled.

This paper's title comes from one of the students in our study who explained, "we constantly have to navigate different ontologies, epistemologies, and axiologies around western and Indigenous systems. It's difficult because there are places where we can't be true to our beliefs and also be taken seriously by western scientists." Indeed, much has been written about these distinct systems; the hegemony of western science knowledge systems; and the ways Indigenous epistemologies, knowledges, and/or sciences can and should be honored and leveraged. As Brayboy and Castagno (2008) have argued elsewhere, "mainstream science presents a number of differences and conflicts for some Indigenous students and tribal communities because of the assumptions, values, and hegemony it continues to perpetuate" (p. 741). This is why numerous Indigenous scholars have argued for the opening up of Western science so that Indigenous knowledges, sciences, ways of being and doing, and epistemologies can be centered (e.g., Cajete 2000; Duran 2007; Wildcat 2005). Such opening up of Western science, and the related centering of Indigenous sciences, is important because Western science is often presented in ways that are irrelevant and/or disconnected from the daily lives of Indigenous students (Kawagley et al. 1998), and because Western epistemologies are presumed to be superior to other, including Indigenous, epistemologies (Nelson-Barber and Estrin 1995).

We agree with Bang and Medin (2010) that dichotomizing Western and Indigenous sciences only serves to oversimplify both and, often, reinscribe harmful binaries. In fact, all human beings interpret and engage the world through particular cultural lenses, so in this way, it can be said that all cultures have their own science (Snively and Corsiglia 2001). But for the purposes of our research, it is important to highlight that Indigenous peoples have been scientists and inventors of scientific ideas forever, despite the fact that this is

not often acknowledged by mainstream, Western science (Brayboy and Castagno 2008). It is widely accepted by Indigenous scholars that within Indigenous knowledge systems, science is not something that you do but rather it “is life” (Ollerenshaw and Lyons 2002) and is engaged to ensure the survival of a people. Marker (2019) has talked about this by noting that “doing science and being a scientist is a fused category” (p. 200). This is evidenced, for example, in the fact that there are no words in the Yupiaq language for many of the concepts central to Western science, nor for the various sub-fields of Western science (Kawagley 1990). Thus, Vine Deloria (1992) suggests we frame these conversations around metaphysics, rather than around concepts like science or religion.

We hope the research we report on here complements and extends this robust conceptual work by focusing on the ways these epistemologies, axiologies, and ontologies translate into specific and concrete conflicts experienced when Indigenous students and professionals engage in STEMM practice. In the following sections, we provide some background on the larger research project from which this paper is drawn, but the focus here is on the following research question: How do Indigenous students and professionals in STEMM navigate the ethical/cultural/spiritual conflicts they experience? We will briefly explain the STEMM-related conflicts experienced by Indigenous students and professionals in our study. After providing an overview of the conflicts, we discuss the themes that emerged from the data about how Indigenous students and professionals navigate the conflicts.

Methodological framework and research design

Our research employed a blend of Grounded Theory and Critical Indigenous Research Methodologies to investigate the ethical considerations faced by Indigenous STEMM students and professionals in the western United States. Grounded Theory (Glaser and Strauss 1967) is an inductive, iterative, and comparative methodology aimed at theory-development (Charmaz 2006). Researchers in this tradition move back-and-forth between data collection, data analysis, and writing to ultimately arrive at a clear understanding and/or explanation of a particular phenomenon (Corbin and Strauss 2008). Although there are various iterations of Grounded Theory, they all share a focus on “studies of individual and collective actions and social and social psychological processes” (Thornberg and Charmaz 2012, p. 42). Critical Indigenous Research Methodologies (CIRM) have developed out of a long tradition of Native scholars and communities who have argued that research with Indigenous peoples must adhere to a set of guiding principles (Smith 1999). These principles include fore-fronting the inherent sovereignty and self-determination of tribal nations, honoring and building on relationships within and between researchers and community members, and pursuing research questions that will advance community needs and interests (Brayboy, Gough, Leonard, Roehl, and Solyom 2012). Our research necessitates a combining of both Grounded Theory and Critical Indigenous Research Methodologies because methodology, by definition, informs how and why research is pursued, drives the assumptions of the research and the selection of methods, and situates research in a particular place and time. This project developed explicitly out of the authors’ relationships, experiences, and expertise around Indigenous education, STEMM pathway concerns, and Native Nations’ desires for highly educated STEMM professionals who can serve their communities.

The research began with an online survey sent to two distinct participant groups: Indigenous post-secondary (undergraduate and graduate) students and Indigenous professionals

in the western United States region. The table below provides a demographic overview of the survey respondents (Table 1).

Using purposive sampling (Etikan, Musa, and Alkassim 2016), Indigenous students and professionals were recruited for this study through student and professional listservs (i.e., American Indian Science and Engineering Society, Society for Advancement of Chicanos/Hispanics and Native Americans in Science, Native Research Network), professional connections, and snowball sampling. Participants were included if they (1) identified as American Indian/Alaska Native, (2) were an undergraduate student, graduate student, or professional in a STEM field at the time of the study, and (3) resided in the western U.S. at the time of the study. The western United States region was defined as all states inclusive and west of New Mexico, Colorado, Wyoming, and Montana. The Northern Arizona University Institutional Review Board (IRB) approved this study, and all participants provided informed consent. IRB approval was obtained prior to the collection of any data. A total of 408 participants met inclusion criteria and completed the survey (206 Indigenous professionals and 202 Indigenous students).

Descriptive statistics were used to describe participants' demographics, including their STEM discipline, age, gender, education level, where a participant grew up, and where a participant currently lives. Before asking about specific types of cultural, ethical, and/or spiritual conflicts individuals had experienced, participants were asked to report their level of agreement on statements regarding cultural, ethical, and/or spiritual perspectives using a Likert Scale. Means and standard deviations were used to summarize Likert Scale responses. Finally, participants were asked if specific STEM-related activities (e.g., animal dissection, research with tissue samples, development efforts on tribal lands, etc.) were part of their STEM field; if they had ever completed the specific STEM-related activity; and if completing the activity was ethically, culturally, or spiritually concerning for them. Frequencies and relative frequencies were used to summarize STEM-related activity information. All analyses were conducted using SAS V9.4 (SAS Inc., Cary, North Carolina). We followed up the survey with 17 student interviews and 13 interviews with professionals. The qualitative data from both the survey (i.e., open-ended questions) and the interviews were inductively analyzed using open coding methods (Glesne 2010), followed by focused coding using the constant comparative method (Corbin and Strauss 2008).

Are there ethical conflicts experienced by Indigenous people in STEM?

This paper will specifically report on the qualitative data that speak to the negotiation processes utilized by participants, but it is important to first establish that Indigenous people in STEM do indeed experience unique cultural, ethical, and spiritual dilemmas given the norms and expectations of their fields and their spiritual and cultural commitments. The table below indicates the responses to three general statements suggesting that there are unique cultural informed ethical conflicts faced by Indigenous people in STEM (Table 2).

Students agreed slightly more strongly than professionals on all three of these statements. Both students and professionals indicated higher level of agreement to American Indian/Alaska Native people in STEM fields have unique cultural, spiritual, and/or ethical issues to consider compared to the other questions posed. These results resonate

Table 1 Demographic characteristics of STEMM students and professionals, 2019

	Students (<i>n</i> = 203)		Professionals (<i>n</i> = 206)	
	<i>N</i>	%	<i>N</i>	%
STEMM discipline/field				
Life sciences	45	22.2	47	22.8
Physical sciences	22	10.8	24	11.7
Engineering	33	16.3	45	21.8
Mathematics	31	15.3	21	10.2
Computer sciences	12	5.9	21	10.2
Health sciences	55	27.1	36	17.5
Other	5	2.5	12	5.8
Age				
18–22 years	97	47.8	7	3.4
23–29 years	82	40.4	44	21.4
30–40 years	22	10.8	103	50.0
41–50 years	2	1.00	41	19.9
> 50 years	0		11	5.3
Gender				
Male	82	40.4	116	56.3
Female	116	57.1	90	43.7
Other	5	2.5	0	
Education level				
Some college, no degree completed yet	102	50.3	11	5.3
Associate degree	20	9.9	18	8.7
Bachelor's degree	55	27.1	112	54.4
Master's degree	22	10.8	53	25.7
Professional or terminal degree	0		11	5.3
Other	4	2.0	1	0.5
Where participants grew up				
Urban	39	19.2	47	22.8
Suburban	44	21.7	34	16.5
Rural	70	34.5	67	32.52
Reservation	49	24.1	57	27.7
Other	1	0.5	1	0.5
Where participants currently live				
Urban	102	50.3	110	53.4
Suburban	53	26.1	63	30.6
Rural	25	12.3	13	6.3
Reservation	22	10.8	18	8.7
Other	1	0.5	2	1.0

with the literature summarized above regarding Indigenous Knowledge Systems and Native Science and, therefore, provide important empirical support for this rich conceptual body of scholarship.

Table 2 STEM students' and professionals', perceptions of cultural, ethical, and/or spiritual conflicts in STEM fields, 2019

	STEM students (<i>n</i> = 203)		STEM professionals (<i>n</i> = 206)	
	Mean	SD	Mean	SD
I think American Indian/Alaska Native people in STEM fields have unique cultural, spiritual, and/or ethical issues to consider	4.10	0.88	3.88	1.02
Indigenous people in STEM majors/careers have to set aside some of their cultural, ethical, and/or spiritual beliefs in order to succeed in their career	3.54	1.06	3.30	1.13
Indigenous people in STEM majors/careers can't always do what is expected in their classes/profession because of cultural, ethical, and/or spiritual beliefs	3.42	1.07	3.14	1.12
Responses to questions were on a Likert Scale where 1 = Strongly Disagree; 2 = Somewhat Disagree; 3 = Neither Agree or Disagree; 4 = Somewhat Agree; and 5 = Strongly Agree				

As explained above, survey respondents were also asked about whether certain STEMM activities were generally part of their specific STEMM discipline and if that activity was something in which they participated. Activities inquired about included archaeological field work; visiting, economic development, research, and investigating environmental hazards on Indigenous sacred sites; designing or testing infrastructure, assessing natural resources, commercial or economic development, research, and investigating environmental hazards on tribal lands; observing animals or humans in clinical, experimental, and natural settings; genetics; examining human or animal cadavers; investigating weather; and discussing sacred or ceremonial knowledge. If a respondent indicated ever participating in a particular activity, they were then asked the extent to which that activity was culturally, ethically, or spiritually concerning for them. This survey data indicate that STEMM disciplines and work that involves human remains, genetics, tribal lands, or Indigenous sacred sites is often viewed as more ethically concerning for many Indigenous students and professionals compared to activities outside this scope.

Navigating the conflicts

Our survey and interview data indicated a clear pattern: Indigenous students and professionals face unique cultural, spiritual, and ethical conflicts in STEMM and they engage in thoughtful and intentional strategies to navigate those conflicts. We heard this message over and over again, as illustrated by this example from a professional who said, “I believe that the constant battle that Native people in STEMM face is how do I conduct my professional tasks with my cultural, ethical, and spiritual beliefs.” Similarly, another professional elaborated a bit in her explanation:

I think that there are many cultural, ethical, and/or spiritual issues that Native people face in the STEMM professions. While each individual is different, they have to reconsider various fields due to their personal values. A person who is not Native, will likely not have the conflicts. In the STEMM field, it is based on facts and interpretation of those facts. Which may make it easier to make decisions. But a Native person may have a personal conflict when they reflect on the teachings they grew up with. Some are able to set them aside and move forward. Others may have a difficult choice to make.

Our purpose in this paper is to explore the various strategies employed by Indigenous students and professionals in STEMM fields to navigate these experiences and choices. The qualitative data provide rich narratives that center the voices of those who often are not highlighted in STEMM policy, practice, and research. We turn now to those voices to highlight how Indigenous students and professionals navigate the ethical conflicts they have experienced along their STEMM pathways. Three broad themes emerged from the data about the strategies used in response to the conflicts: (1) teaching others and leveraging their support, (2) engaging in ceremonial practices to provide protection and correction when needed, and (3) being in the right mindset and/or acting in the right ways.

Teaching others and leveraging their support

One of the most common navigational strategies mentioned by both students and professionals in our research is to educate others about any conflicts that arise. Most of the individuals who discussed this strategy talked about how it ultimately resulted in a positive outcome, but there were certainly exceptions to that. In addition to teaching or otherwise informing people about the conflicts, many Indigenous students and professionals shared examples of how they leveraged certain individuals' support to either expand the impact of that educational effort or assist them in some other outcome.

Some survey respondents talked about how they are prohibited from being outside, eating, or sleeping during an eclipse. In all of these cases, they could inform their co-workers or professors about the restrictions without any negative repercussions. As one student explained, "In my culture we are not allowed to watch an eclipse, eat, drink, or sleep during an eclipse. So I miss work and my family misses school the entire day when an eclipse happens. I just let my boss know it's a cultural issue and take leave for that day. In the future I will do the same." Another student talked about the same restrictions she has during an eclipse and her school's neutral response: "I am one of a couple of Native students at my school so my school didn't know about this. It wasn't an issue; it would have been if the staff didn't allow me to stay inside." Learning how to engage in these conversations and advocate for oneself is a common experience among Indigenous students in STEMM, and it is a navigational skill that will serve them well into their careers. A professional shared this insight: "[Most] of the professionals I work around or work with do not have the same spiritual or cultural upbringing as I have...I come across a lot of misinformed or biased or stereotypical responses by individuals that I have chosen to correct. This has only enhanced my ability to be empowered about advocating for my Native American heritage."

The opportunities for Indigenous students and professionals to educate others about the cultural, ethical, and spiritual conflicts that emerge in STEMM are numerous and diverse. We provide three examples here that are from three distinct STEMM areas. A student narrated the first example:

I shared some information about traditional plant medicines with a professor. He suggested researching one of the plants I mentioned. He thought it would be a great strawberry preserver. In my culture, you do not exploit the plants. I felt like my information was being taken advantage of. I told the professor I was not comfortable with exploiting a plant that we use for medicine.

A STEMM professional shared another example related to soil moisture probes and how he chose to educate a supervisor.

I was once asked to take soil moisture probes to my fields at Hopi to prove that our ancient techniques conserved soil moisture. I told them I would not and that we have over 2000 years of replication, so no need to prove anything. In addition, I also told them that our techniques were related to our survival and if they did not work, we would not still be here.

A number of people were more general in their explanations, but all shared a common message that the individual explained something to someone, and that person listened and accommodated. A common word in these narratives was "respectful." This is exemplified by the civil engineer who came across ancestral ruins and pottery while

field staking for a proposed water line; this individual explained “why it was important in our culture to not go near any ruins or touch or bother pottery to my non-Native coworker and helped him understand and he was respectful.” And finally, another professional explains at some length a common conflict she faces, how she informs others about her stance on the issue, and the gratitude she has for others who support her position.

I am in a position where grant funders have typically asked for increased recruitment of American Indians/Alaska Natives into genetic research and/or clinical trials. In these particular cases, I am not comfortable conducting those types of tasks because I do not want to be misleading to tribal community members. I am aware of the cultural sensitivity of biological samples and its role in their spirituality. My response to those requests are, “I am Native American and I would not participate in those types of studies. I would not have any part of my cells willingly involved in research studies because I am not aware of what you will do with my cells and/or what my cells may come into contact with in a research lab. What researchers choose to do with my cells in a research lab may have harmful effects to my wellbeing, if not immediate but later in life.” And because of my own personal reasons, I am reluctant to ask another American Indian/Alaska Native to do that or comprise their traditions, beliefs, and/or spirituality. I am most thankful that I have the support of my superiors in voicing my concerns to those who may not understand.

Indeed, having the support of others—especially superiors—is critical to the successful navigation of these conflicts.

Unfortunately, it does not always go well when Indigenous students and professionals attempt to teach or otherwise engage others in learning about the ethical conflicts they experience. An Indigenous professional reflects on an example from early in his career and highlights how seemingly “small” examples can have a lasting impact:

My discipline is chemical engineering and one aspect of this is petroleum engineering. There was one instance in school where I was arguing against oil drilling in ANWR [Arctic National Wildlife Refuge] due to environmental and tribal concerns. The other students didn’t get it and wanted to drill. That’s a really small example early on in my career, but it showed me how my consciousness of the environment wasn’t valued as much by others in that space.

There is a wide body of literature on microaggressions (Sue 2010), and this person’s memory illustrates that microaggressions and feelings of being different within STEM settings can also be related to differences in ethical, cultural, and spiritual values. A student narrates a similar idea, and her concern about how her professors may perceive certain decisions she must make.

I feel that it is hard to have to explain to professors your cultural beliefs that inhibit a Native person to participate in working with cadavers. I always want to engage and participate fully when I am in a class, so I felt like it may have given the indication that I was not as invested as my other non-Native classmates. I’ve also seen how most of my non-Natives peer are not as affected by environmental issues such as uranium exposure, water contamination, or situations like the Gold King mine spill. So in class when I would speak up about these issues, I felt like they did not comprehend how environmental issues can affect people, community, and a whole tribe.

As this student notes, it can be "hard" for students to be in the role of educating their peers and, especially, their faculty members. Indeed, this is a role that is sometimes fundamentally opposed to a student's cultural norms (Gilmore, Smith, & Kairaiuak 1997). Although an outsider may consider the teaching that many Indigenous people in STEM offer as a positive and conflict-free approach to the kinds of dilemmas highlighted in our research, that is not always the case. Feeling uncomfortable about being in such a role is a very real possibility that can have significant impacts on an individual's sense of belonging and identity. And in the most extreme cases, the impacts can include negative consequences for one's grades and graduation (Canel-Çinarbaş & Yohani 2019), or career advancement (Mihesuah & Wilson 2004). A student offers this example:

Touching human remains was a big issue for me. Touching people's remains is very bad in Navajo culture, but in order for me to get tested and receive a grade for the class, I had to analyze and touch the human remains. I tried to explain my side to the instructor but she said that it was my choice but my grade would be jeopardized over it.

The framing of this issue as a "choice" made by the student is incredibly problematic, and while we hope that this is an exception rather than a norm, it deserves some attention. Faculty in STEM disciplines should be well-informed about the ethical dilemmas for some Indigenous students of working with human and animal remains. When students are positioned as having to "explain" this fairly common spiritual, cultural, and ethical conflict, they are unnecessarily burdened with additional work not required of their peers. Furthermore, framing these conflicts as a choice a student makes suggests an individualistic, seemingly neutral binary that fails to account for diverse spiritual, cultural, and ethical identities. Indigenous people in STEM pathways should not be required to "choose" between their personhood and a grade or promotion.

Ceremony, protection, and correction

The second most common navigational strategy mentioned by the Indigenous students and professionals in our research was to engage in ceremonial activities for both protection prior to an anticipated conflict and correction after a conflict had been experienced. The nature of the ceremonial activities varied by individual, as well as by tribal affiliation, but there was a strong common theme in turning to ceremony to navigate the spiritual, cultural, and ethical conflicts Indigenous people in STEM fields face. A professional captures this general sentiment well when he shares, "I think obtaining guidance, authorization, and numerous amounts of prayer and teachings help cope with any cultural, ethical, and/or spiritual issues that arise for Indigenous professionals in STEM."

Depending on the location of the person in relation to their tribes' traditional homelands and/or reservation, participation in formal ceremonies may or may not be possible. A medical school student shares his experience, which included ceremonies offered by an Indigenous faculty member.

I am in medical school and one of the biggest issues was figuring out how to approach dissecting human cadavers, because traditionally we are not supposed to touch dead bodies or be around death. At [my medical school], we have support for Indigenous students through the Indians into Medicine program and a faculty member who is Indigenous and practices traditional medicine in addition to western medicine. He

has served as a mentor to myself and other Indigenous students in the MD program, and he provided a blessing ceremony for us before we started our program and we went with him when he performed a blessing ceremony in the anatomy lab where we dissect the cadavers.

Attending a school with this sort of formal and institutionalized support was the exception among our survey respondents, but we share it here as a model example. Other students and professionals talked about going home to participate in ceremonies, but this often comes at significant cost to the individuals and their families. These costs may be financial, such as the funds to travel and salary reductions, as well as emotional and relational. But the students and professionals who rely on this as a strategy clearly understand the benefits to outweigh the costs.

Since participating in more formal ceremonial activities is not often possible because of geographic and time constraints, many Indigenous students and professionals engage in more independent ceremonial activities. These include prayer and wearing or carrying culturally and spiritually significant items. One student shares:

In [biology] labs and classes we have been around dead animals to experiment on or dissect. Additionally, we saw videos of owls or snakes eating other animals which is something my tribe is told not to look at or watch. This can be a negative moment for many Navajos because it signifies bad luck or enemy way approaching you. After these events (sometimes before if I knew it would happen), I would pray with corn pollen and wear turquoise jewelry that day to protect myself.

A professional echoes a similar reliance on prayer as she reflects back on her graduate school experiences: “In graduate school, I had to work with cell cultures, and I was respectful of the cells because I still consider them a living creature. I always did a prayer after I had to collect RNA and DNA from the cells.” These examples are representative of many other students and professionals who shared very similar sentiments, experiences, and examples of the ways they engage ceremonial and other spiritually significant practices in order to both protect themselves and realign, correct, or otherwise address culturally, spiritually, and ethically problematic experiences in their STEM pathways.

Being in the right mindset and acting in the right ways

Two themes emerged that were unique to either students or professionals. Many students talked about what one called being “in the right mindset,” which refers to the way some students prepare themselves mentally to engage in certain activities. Although this theme was not explicitly present in the data from professionals, some of them did speak about the ways they act and engage with their surroundings so as to ensure appropriateness. We discuss these themes together because our research team views them as deeply connected and, perhaps, a sort of progression as some individuals grow and mature into their professional roles.

The students who talked about being in a particular mindset and/or thinking about the conflict in a certain way were all working within medical and biological contexts that involved deceased human bodies or animal remains. For some individuals, the right mindset requires a sort of separation of their cultural beliefs and their school work, as explained by one student:

Being around dead bodies, as in the morgue, or taking donations from deceased [bodies] goes against many cultural beliefs. One should not disrupt a dead body and giving up your organs for donations means that you would not be able to pass on to the afterlife. I am an Urban Native, but I do hold my cultural beliefs closely. It is difficult to admit, but when placed in these situations I often leave my cultural beliefs outside of my education and work.

This was not the only student who used words like "difficult" and "leave my cultural beliefs outside" while narrating the ways they navigate these conflicts. Another student explained how she engaged in self-talk to get through a similar experience: "the removal of animal carcasses was a big challenge for me. I told myself to believe in science and finally completed the experiment." From an outside perspective, it may seem obvious or simple to "tell yourself to believe in science," and indeed most (if not all) readers of this journal likely share a common belief in science. But this student is signaling the fact that some science rubs against other science, culture, and knowledge systems in ways that may not be obvious to others. Another student described his experience this way: "Dissection of cadavers for medical education is needed, however, the context of the situation you have to be in the right mindset. [I] had the medicine man perform ceremonies before my duty." For this student, it was important to be in the "right mindset," as well as to engage in ceremonies for protection during the required task of working with cadavers. All of the students who spoke about being in the right mindset connected this to a larger goal or plan they had to complete a particular educational pathway and, often times, to work in service to their tribal communities. This is highlighted by the student who shared, "I think working with human cadavers in medical school will be my biggest issue. It will definitely be something to get over and I am nervous about [it]. These things are necessary for me to learn, so I am able to go back to the reservation to help my people." The idea of enduring something that is exceedingly difficult in order to fulfill a desire or plan to serve one's community is not new (Brayboy 2005) and, in fact, is a common theme across underrepresented students in higher education (Roberts et. al. 2020). However, what is uniquely highlighted in our research is that the nature of the difficult situations for some Indigenous students in STEMM is fundamentally spiritually and ethically based.

To further illustrate and elaborate on this conflict, we share another student's narrative at length:

I don't want to speak for every Native when I say this, but I think often times when we are pursuing STEMM degrees, there are going to be a lot of issues we face that don't align with our cultural and spiritual values and beliefs, but as we are more and more assimilated into mainstream society such as when pursuing a degree, we learn to make the choice on how to proceed even if there are issues that arise. It's difficult to navigate, but the calling that we feel to pursue a higher education, and work hard as an individual is also an important aspect of our spirituality and therefore oftentimes, we are more open to doing something that we otherwise would not have felt comfortable doing. Our own calling as an individual and working hard toward a goal and setting out to accomplish a goal is also an important aspect of our cultural beliefs; therefore, we make decisions, for example, to dissect an animal even though it's not in line with our cultural beliefs, but we are doing it for the sake of our goal, which is also an important aspect of our cultural beliefs. As you can see it's a conflict between making the choice to do something that goes against our traditions but also a conflict between our spirituality and the

goals we have as an individual, which is also an important aspect of our culture, therefore it is almost as if it is a double-sided issue that we face. We get through with prayers, and support from others going through similar experiences.

This student captures a number of the themes our research team found throughout the data. She explains how the pursuit of higher education along STEMM pathways is “double-sided” in terms of the potential for cultural, spiritual, and ethical conflicts.

Among the qualitative data from the professionals in our research, we did not identify the same theme of being in the right mindset, but a number of the ways professionals narrated their actions suggested similar mindsets. One professional did reference being in the “right” space spiritually, emotionally, and mentally. That person shared, “many Natives have to spend a lot of time doing activities to keep their heart, spirit, mind right that are not valued or considered in their promotion and tenure or advancement in the private sector/government positions.” Other professionals focused on the right and appropriate actions they take in navigating cultural, spiritual, and ethical conflicts in STEMM. Consider this example:

We work with cancer survivors in and around the Navajo Nation. As our study evolved, we learned how providing services to these cancer survivors was delicate in that many Navajos still don’t like to talk about disease or illness. Culturally, talking about them was equivalent to inviting the disease into your life...For the most part, when we would go out to recruit, we needed to be extra sensitive to not speak loudly of our work, to allow the interested person to lead the conversation with questions, and to act humble regarding our interest in recruiting them. We also purposely designed our logo to not indicate the disease we are fighting but instead focused on health.

This professional demonstrates deep knowledge about the spiritual, cultural, and ethical dilemmas that exist in cancer-related work with some Indigenous communities, and they explain specific strategies (e.g., how to speak, demonstrating humility, logo design) they’ve learned. Part of what is highlighted here is an intentional and strategic way of communicating as an Indigenous professional in STEMM. Another example of this is highlighted by the following person’s narration of their experience as an Indigenous social scientist working in cross-disciplinary and cross-racial teams:

I have to be limited to what I can speak of because of my own ethics related to social science research within tribal lands and Indigenous communities. The research I engage in focuses on the impacts of climate change to Indigenous community health and wellbeing. I do this through tribal community interviews and socio-economic assessments, and in partnership with biologists and chemists who study changes in the ocean. As an Indigenous social scientist, I aim to change how we talk about this kind of research. That is to say, we are not “discovering” anything, we are simply working in partnership with Indigenous communities to capture what they are willing to share. We value traditional ecological knowledge as Indigenous science. When it comes to being in spaces with non-Native scientists, I hear how they speak about their own “discoveries” and find it harmful. An example of this is when they claim to have “discovered” a negative impact on a culturally important species. They do not share this knowledge with empathy for the animal, nor understand the harm of how they are speaking about the loss of our relatives.

This professional's navigational strategies include limiting what they say in certain contexts, valuing traditional ecological knowledge, and changing how research in Indigenous communities is discussed. For this person, all of these make up what it means to act and engage in the right ways as an Indigenous person in STEMM.

Of course, acting and engaging in the right ways will look, sound, and feel different depending on the individual, community, and context. This final example of a professional explaining what it means for them to act in the right ways highlights their understanding of how best to engage youth in STEMM-related work:

I often experience ethical issues when working with tribal youth on environmental issues. When explaining the research and providing a hands-on approach to the subject, I have to carefully explain both sides to the issue and refrain from sharing personal views. This can be challenging when the issue at hand provides a significant number of jobs and revenue, but is damaging the land. I will frame it from both viewpoints. I will tell tribal youth that they will have to make these decisions when they are adults. That they have to consider their personal and cultural values that are important to them. I tell them not everyone will have the same opinion and it is important that they carefully consider all options.

Through modeling, this professional introduces young Indigenous people to the kinds of spiritual, ethical, and cultural conflicts they will need to navigate, but he does not necessarily give a prescribed path for how to do that. For him, acting and engaging Indigenous youth coming through STEMM pathways requires the careful presentation of various perspectives and knowledge systems.

Conclusion

Indigenous people are the *most* underrepresented ethnic group in STEMM fields. More equitable representation of Indigenous peoples in STEMM is not just a moral imperative; it is also necessary to ensure diverse, high-quality STEMM perspectives and approaches. Our research explored whether and how culturally embedded ethical barriers contribute to this underrepresentation, and our findings can inform policies and practices to minimize the impact of these factors. We found three general themes in the data about how Indigenous students and professionals navigate the cultural, spiritual, and ethical conflicts they experience in STEMM fields. These navigational strategies include (1) teaching and leveraging the support of others, (2) engaging in ceremonial activities for both protection and correction, and (3) being in the right mindset and acting in the right ways. We would be remiss to not mention that all three of these navigational strategies are only necessary because mainstream, predominantly White universities and industry entities have not generally been willing to adapt and adjust their standard practices. As Michael Marker (2019) reminds us, we should always be asking what institutions are doing to evolve, rather than solely examining and seeking to honor the ways individuals within institutions must adapt. Our hope is that by providing empirical evidence of the multiple ethical, spiritual, and cultural conflicts Indigenous students and professionals face in STEMM practice, institutions (i.e., universities, industry, employers) will consider changes they can make. Indeed, the anecdotes many of us have individually experienced are actually part of a widespread pattern across the STEMM disciplines. We should not be content knowing that students and professionals

such as those in this study have developed complex navigational strategies for managing the standard practices, norms, and expectations along STEMM pathways.

Some individuals ultimately decide that the conflicts are un-navigable and that changing pathways is the best option. Our future work will explore these decisions to leave STEMM in greater detail. Still, it is important to acknowledge here that changing course is one navigational strategy employed by some Indigenous students and professionals in STEMM fields. Changing careers is not a failure, not an indication of weakness, and not a signal of incompetence. Instead, it is often a thoughtful, strategic, and intentional decision given the experiences, goals, and relationships individuals carry with them along their STEMM pathways. As one young professional explained, “I have always been interested in studying the wellbeing of the whole individual. Issues related to spirituality are largely frowned on in my field, which as a junior faculty member created huge theoretical and ethical issues for me. I felt like I had to put important issues on the back burner or risk not getting tenure.” A number of other professionals and students echoed this idea of compartmentalizing their spiritual, cultural, and ethical identities from their work. One professional explained that “many STEMM professionals must sacrifice their unique cultural and moral spirit to be qualified for this job” and another said “I believe that Indigenous people in STEMM occupations must abandon some of their cultural, moral, and spiritual beliefs in order to succeed at work.” But as we’ve highlighted throughout this paper, many Indigenous students and professionals find ways to navigate these conflicts and succeed along their STEMM pathway.

As a research team, we have been humbled by the learning journey this study has carried us along. Although we shared a common set of anecdotal experiences prior to this research that suggested some of the findings we explained in this paper, we had no idea the extent to which these ethical, cultural, and spiritual conflicts were widespread or impacting the STEMM pathways of Indigenous people across the western United States. While the rich body of literature on Indigenous epistemologies and Native science suggests these sorts of conflicts would be present in practice, we are now beginning to amass a dataset that can directly speak to the ethical, cultural, and spiritual conflicts in practice. In our study, the students, and especially the professionals, demonstrated resourcefulness, thoughtfulness, and incredible capacity to navigate these conflicts in various ways. As one professional shared, “all people make choices dependent on their survival, we honor our ancestors by making choices that are based on our culture and spiritual journey.” These journeys have much to teach STEMM leaders, faculty, teachers, staff, and employers, but perhaps the most important is the message from this experienced Indigenous STEMM professional: “I believe Indigenous people CAN do what is expected of them in their profession, but it may not be the in the same way.”

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Bang, M., & Medin, D. (2010). Cultural processes in science education: Supporting the navigation of multiple epistemologies. *Science Education*, 94(6), 1008–1026. <https://doi.org/10.1002/sce.20392>
- Brayboy, B. M. J., & Castagno, A. E. (2008). How might Native science inform "informal" science learning? *Cultural Studies of Science Education*, 3, 731–750. <https://doi.org/10.1007/s11422-008-9125-x>
- Brayboy, B., Gough, H., Leonard, B., Roehl, R., & Solyom, J. (2012). Reclaiming scholarship: Critical Indigenous research methodologies. In S. Lapan, M. Quartaroli, & F. Riemer (Eds.), *Qualitative research: An introduction to methods and design* (pp. 423–450). Jossey Bass.
- Brayboy, B. (2005). Transformational resistance and social justice: American Indians in ivy league universities. *Anthropology and Education Quarterly*, 36(3), 193–211. <https://doi.org/10.1525/aeq.2005.36.3.193>
- Cajete, G. (2000). *Native science: Natural laws of interdependence*. Clearlight.
- Canel-Çınarbaş, D., & Yohani, S. (2019). Indigenous Canadian university students' experiences of micro-aggressions. *International Journal of Advanced Counseling*, 41(1), 41–60. <https://doi.org/10.1007/s10447-018-9345-z>
- Castagno, A., & Brayboy, B. M. (2008). Culturally responsive schooling for Indigenous youth: A review of the literature. *Review of Educational Research*, 78, 941–993. <https://doi.org/10.3102/0034654308323036>
- Caughman, L. (2013). Native American women in science: A historical and cultural perspective. <https://doi.org/10.13140/RG.2.1.1523.8161>
- Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Sage.
- Corbin, J., & Strauss, A. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Sage.
- Deloria, V. (1992). Relativity, relatedness, and reality. *Winds of Change*, Autumn, 35–40.
- Duran, P. (2007). On the cosmic order of modern physics and the conceptual world of the American Indian. *World Futures*, 63, 1–27. <https://doi.org/10.1080/02604020601049939>
- Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American Journal of Theoretical and Applied Statistics*, 5(1), 1–4.
- Gilmore, P., Smith, D.M., & Kairaiuak, A.L. (1997). Resisting diversity: An Alaskan case of institutional struggle. In M. Fine, L. Powell, L. Weis & L. M. Wong (Eds.), *Off-white: Reading on society, culture and race* (pp. 90–99). Routledge.
- Glaser, B., & Strauss, A. (1967). *The discovery of grounded theory*. Aldine.
- Glesne, C. (2010). *Becoming qualitative researchers: An introduction*. Pearson.
- Ingram, J. C. (2009). Establishing relationships and partnerships to engage Native American students in research. In M. Boyd, & J. Wesemann (Eds.), *Broadening participation in undergraduate research: Fostering excellence and enhancing the impact* (pp. 269–280). Council on Undergraduate Research.
- Kawagley, A. (1990). Yup'ik ways of knowing. *Canadian Journal of Native Education*, 17, 5–17.
- Kawagley, A., Norris-Tull, D., & Norris-Tull, R. (1998). The Indigenous worldview of Yupiaq culture: Its scientific nature and relevance to the practice and teaching of science. *Journal of Research in Science Teaching*, 35(2), 133–144. [https://doi.org/10.1002/\(SICI\)1098-2736\(199802\)35:2B133::AID-TEA4C3.0.CO;2-T](https://doi.org/10.1002/(SICI)1098-2736(199802)35:2B133::AID-TEA4C3.0.CO;2-T)
- Marker, M. (2019). Indigenous success stories as disquieting colonization: Thoughts on new times, and old thoughts about place-ness. *Cultural Studies of Science Education*, 14, 199–204. <https://doi.org/10.1007/s11422-018-9873-1>
- Mihesuah, D., & Wilson, A. (2004). *Indigenizing the Academy: Transforming scholarship and empowering communities*. University of Nebraska Press.
- Nelson-Barber, S., & Estrin, E. (1995). *Culturally responsive mathematics and science education for Native students*. Native Education Initiative of the Regional Educational Labs.
- Ollerenshaw, J., & Lyons, D. (2002). Voices in a reservation school: A sonata-form narrative from a professor and a Dakota pre-service teacher about their professional and practical knowledge teaching science in culturally responsive ways. In *Paper presented at the annual international conference of the association for the education of teachers in science*, Charlotte, NC.
- Roberts, T., Gutiérrez, L., Gibbs Grey, T., & Stanbrough, R. (2020). Trailblazers, reciprocity, and doctoral education: The pursuit of critical race praxis and survivance among doctoral students of color. *The Journal of Higher Education*, 92(2), 227–251.
- Smith, L. T. (1999). *Decolonizing methodologies: Research and indigenous peoples*. London: Zed Books.

- Snively, G., & Corsiglia, J. (2001). Discovering indigenous science: Implications for science education. *Science Education*, 84, 6–34. [https://doi.org/10.1002/1098-237X\(200101\)85:1B6::AID-SCE3C3.0.CO;2-R](https://doi.org/10.1002/1098-237X(200101)85:1B6::AID-SCE3C3.0.CO;2-R)
- Sue, D. W. (2010). *Microaggressions in everyday life: Race, gender, and sexual orientation*. Wiley.
- Thornberg, R., & Charmaz, K. (2012). Grounded theory. In S. Lapan, M. Quartaroli, & F. Riemer (Eds.), *Qualitative research: An introduction to methods and design* (pp. 41–68). Jossey Bass.
- Weldon, S. (2007). *Science & religion: A historical introduction*. Johns Hopkins University Press.
- Wildcat, D. (2005). Indigenizing the future: Why we must think spatially in the twenty-first century. *American Studies*, 46, 417–440.
- Williams, D., & Shipley, G. (2018). Cultural taboos as a factor in the participation rate of Native Americans in STEM. *International Journal of STEM Education*, 5, 17. <https://doi.org/10.1186/s40594-018-0114-7>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Angelina E. Castagno Ph.D., is the Director of the Institute for Native-serving Educators, and a Professor of Educational Leadership and Foundations at Northern Arizona University. Her teaching, research, and consulting focus on equity and diversity in U.S. schools, with a focus on Indigenous education. She is an Associate Editor for the *Journal of American Indian Education* and has authored or edited four books and numerous articles in peer reviewed national and international journals. Her most recent edited volume was published in 2019 and is called *The Price of Nice: How Good Intentions Maintain Educational Inequity*.

Jani C. Ingram Ph.D., is Regents Professor of Chemistry and Biochemistry at Northern Arizona University. She investigates environmental contaminants with respect to their impact on health. A major part of her research is focused on characterizing uranium and arsenic contamination in water, soil, plants, and livestock. A critical aspect of her research is to foster collaborations with the Native American community and leaders to build trust, obtain access to field samples and gain insights into their health concerns.

Ricky Camplain Ph.D., is an Assistant Professor in Northern Arizona's Department of Health Sciences and an Epidemiologist at the Center for Health Equity Research. Her research focuses on chronic disease prevention and health promotion (e.g., physical activity and sedentary behavior) with a primary focus on understanding, in partnerships with communities, the health needs of vulnerable populations, particularly the intersection of being Indigenous and incarcerated. She employs epidemiologic methods to determine how culture, policy, and the social and structural determinants of health in the correctional system can impact healthy behavior and social justice.

Davona Blackhorse MA, is a Clinical and Mental Health Counselor and advocate working to raise awareness of Uranium mining in the Southwest. She graduated with a Masters in the Clinical and Mental Health Counseling program at Northern Arizona University. Her research concentrated on cultivating literature on the psychological impact of Uranium exposure on the Navajo Reservation and historical trauma among Native Americans. She is now pursuing a Ph.D. in Interdisciplinary Health with an emphasis in Psychosocial Health.