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Wayfinding as a concept for understanding success among Native Americans in STEM: "learning how to map through life"

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Title

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“*learning how to map through life*”

Abstract

This paper discusses findings from 40 ethnographically inspired interviews with 21 Native science professionals conducted in two iterative phases (21 in Phase I and 19 in Phase II), and a structured dialogue workgroup session with a 6-member subset of the interviewees. Interview and group questions were open-ended to allow the participants to drive the conversation. We approached our interpretation of the data as an opportunity for deriving insights into the nature and meanings of participant narratives and experiences, why they present their stories in a particular way, and what this can tell us about the research questions we are exploring. We identify how the way they view themselves and the way they engage with the world has been transformed through their experience in obtaining a STEM degree at historically white institutions and working as a STEM professional. We argue that these changes allow for repurposing of STEM content knowledge to (re)connect with culturally defined values and goals. We discuss this transformative process as involving *wayfinding* and the accumulation of what we call *experiential wisdom*. We contend that the dimensions of this process are not sufficiently captured in concepts widely used to discuss situations of intercultural encounter. Our research builds on research of indigenous scholars who have provided a new way of thinking about Native Americans and science education.

Title

Wayfinding as a concept for understanding success among Native Americans in STEM:
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Creating Native spaces in STEM

...unlike the maps that designate Indian lands as only existing in certain places, wherever we went, there were Natives and Native spaces, and if there weren't, we carved them out.

Mishuana Goeman (2013, p. 5)

How do you learn how to map your life? Gosh ... it's how you interweave everything together ... you have to have confidence, you need to know how to map through life.

Quote from a Native STEM professional

In 1977, a small group of Native American scientists and engineers formed the American Indian Science and Engineering Society (AISES) to develop science-related opportunities in education for Native American youth and to increase the number of Native Americans pursuing careers in science, technology, engineering and mathematics (STEM). Enhancing and supporting Native technological expertise by creating an association for Native Americans to explore and promote ways of thinking about and doing science was understood as necessary for advancing Native sovereignty, self-determination, and leadership (AISES 1985). Since the 1970s and especially over the past decade, culturally sensitive schooling (CSS) (Brayboy and Castagno 2008a,b), culturally responsive schooling (CRS) (Fickel, Macfarlane, and Macfarlane 2017), culturally sustaining and revitalizing pedagogy (CSRP) (McCarty and Lee 2014), informal science education practices (ISE) (Mack, et al. 2012), and Indigenous Art Science (IAS) (McGinty and Bang 2016) have been proposed as pedagogical mechanisms for expanding Native spaces in science education and as strategies for carving out Native arenas in the STEM landscape (Castagno and Brayboy 2008). These educational practices use culturally relevant and linguistically appropriate approaches that value and respect indigenous knowledge(s) (Brayboy and Castagno 2008b) as foundational for classroom dynamics and in the design of the curriculum in science education. Such practices have been demonstrated to have a substantial positive influence on educational outcomes for Native Americans in STEM.

Tribal Colleges and Universities have done much work to craft spaces where Native Americans can pursue science in culturally informed ways. However, historically white institutions that remain the primary conduit for Native Americans to obtain a college degree or graduate education in STEM often do *not* include such culturally responsive or revitalizing approaches. In these academic environments and in STEM professional workplaces, Western scientific ways of knowing often go unmarked and are seen as natural (McGinty and Bang 2016).

And, not unimportantly, many Native American students find themselves attending educational institutions that do not acknowledge the original inhabitants of the lands they now occupy (Ambo 2017). This non-recognition of the past by historically white universities further settles historical and institutional policies that have worked to erase and assimilate Native peoples. In science, the privileging of Western conceptual frameworks and perspectives positions Indigenous ways of knowing as outside the boundaries of or incompatible with the positivistic scientific paradigm used in STEM education at historically white institutions and workplace contexts (Marker 2015) and tacitly, posits Indigenous *people* as intrinsically unable to succeed in science education and unsuitable for working in STEM careers (Brayboy 2004). These kinds of “macrolevel communicated attitudes” about insiders and outsiders (Spencer and Swanson 2016) and epistemological conceptualizations of science shape the experiences that Native Americans have in STEM.

Hilary Weaver (2015) uses the metaphor of the “frontier” as a way to understand such contemporary colonial encounters experienced by Native Americans. “The frontier is much more than a physical place. The idea of frontier...is integrally connected to a sense of identity. Boundaries, such as frontiers, define who belongs where, and conversely, who does not belong or is out of place” (Weaver 2015, p. 27). Using this framework, we can see historically white educational and workspaces as a kind of frontier. In this context, success among Native Americans in STEM education and careers creates “native spaces” that can be understood as a compelling counter to existing power dynamics and a scaffolding for invigorating the “peoplehood” of indigenous communities. The production of “aspirational spaces” and “emergent indigenous geographies” (Coombes, Johnson and Howitt 2012, p. 697) where Native peoples have initiated “anti-colonial projects” (p. 691) have the potential of expanding spaces. Jeff Corntassel (2012, p. 88) sees such “everyday acts of resurgence” in both the conscious acts and everyday lifeways of Native people. The research presented here demonstrates how Native STEM professionals, even without the benefit of culturally informed curriculum or educational practices, are disrupting hegemonic narratives and dynamics that exclude Natives from the spaces of science, and how through their own success in STEM education and careers, they are creating new fields of action based on culturally defined values. These new fields of action contribute to strengthening, and are essential for nurturing capacity for tribal sovereignty (Lomawaima, 2000). Our intent is to honor the experience of our interviewees and use our analysis of it to improve our understanding of the multidimensionality of the dynamics that influence success for Native Americans in STEM.

In this paper, we examine the stories Native scientists and engineers shared with us about their educational experiences in historically white schools and their work as STEM professionals. The schools that interviewees attended (elementary through graduate school) did not have classrooms incorporating CRS, CSS, CSRP, ISE, or IAS, or any sort of culturally informed curricula, although many expressed the wish that they had. The workplaces they have inhabited, particularly at the beginning of their careers, were in primarily mainstream corporate environments. Throughout their lives, interviewees relied on a cultural compass to find their own

way through complex university and professional landscapes, hegemonic science narratives, and complicated personal contexts—both challenging and rewarding. A similar dynamic was reported from interviews with Native American STEM degree holders. Chow-Garcia (2016) found that cultural identity was an important source of motivation for persisting in science programs and influenced professional goals. Here we examine how Native STEM professionals in our study have used their educational and professional experience to “*define a new path*” and “*meld different aspects*” of the way they view themselves and the manner in which they engage with the world--both quotes from participants in this study. The process of repurposing of STEM content knowledge to (re)connect with culturally defined values and goals involves *wayfinding* and the accumulation of *experiential wisdom*. For the individuals involved, this process has resulted in dynamic and recursive changes in perspective.

There is minimal research that specifically focuses on Native Americans in STEM (Chow-Garcia 2016). We contend that the dimensions of repurposing STEM content knowledge is not sufficiently captured in concepts widely used to discuss situations of intercultural exchange and learning. We locate the rationale for this research in the specific history of AISES that began with the vision of its founders in the 1970s that science education could be a path leading to enhanced capacity of Native communities for sovereignty and self-determination. We recognize the pioneering work of Native scholars, including those referenced above. Critical Indigenous scholarship has provided a foundation for an entire area of research and greatly influenced those interested in a new paradigm for thinking about Native American culture and STEM education and careers. Our research builds on this literature.

About this research

Overview

Research for this article was conducted through a collaborative partnership that involves investigators from AISES, the University of New Mexico (UNM), Northwestern University (NU), and later the University of California at Los Angeles (UCLA) (Page-Reeves, et al. 2017b). Our research team includes both professional and junior Native researchers, and our project Advisory Board includes Native education researchers and Native scientists. Data analyzed here were gathered between 2013 and 2016 as part of an exploratory, mixed method study to develop an empirical understanding of Native success in STEM. Success is a term that is often used in STEM education research. We have grappled with the many connotations of this term. For example, if someone is successful does that necessarily mean that others are unsuccessful? Who gets to decide what a successful trajectory looks like? If a person continues to stop out of college in order to care for family members, is this considered to be successful? Together with the project’s Advisory Board, we conceptualized success broadly to include academic and professional achievement, participation in supporting Native community goals, expanding spaces of participation for others and increasing access and ways of participating to include multiple worldviews. This paper discusses findings from 40 ethnographically inspired interviews with 21 Native science professionals conducted in two iterative phases (21 in Phase I and 19 in Phase II), and a structured dialogue workgroup session with a six-member subset of the interviewees.

Methodology

We used an ethnographically inspired, holistic approach (Madden 2010) to conduct a study according to Martin Hammersley's (2008) criteria for qualitative research based on plausibility, credibility, and relevance. We followed Jochen Gläser and Grit Laudel's (2013) framework for theory-driven qualitative content analysis. We consider the concept of culture as fluid, porous, dynamic, relational, negotiated, contextual, and situated in keeping with theoretical stances that have been explored in the anthropological literature (*e.g.*, Ortner 1984), and in education theory (*e.g.*, Lee 2008). As per Michael M.J. Fischer (2007), we adopt a cultural analytic perspective, treating culture as a system that "experimentally" integrates recurrently structured and emergent patterns. We see culture "[as extending] to issues of power, control, resistance, and defiance" (Krumeich et al. 2001, p. 122). We approached our interpretation of the data as an opportunity for deriving insights into the nature and meanings of participant narratives, how and why they present their stories in a particular way, and what this can tell us about the research questions we are exploring (Lambert and McKevitt 2002, p. 212).

Recruitment

Approval to conduct this research was obtained through the Human Research Protections Offices at UNM, NU, and subsequently at UCLA. All study participants provided signed informed consent. Interviewees were identified by AISES staff and our eight-member project Research Advisory Board, which includes four Native scientists and two Native professionals who work on STEM representation issues. The interviewee cohort was intentionally diverse in terms of primary Tribal affiliation, geography, age, discipline, degree, and work sector (see Figure #1), and balanced in relation to gender. Eleven of the interviewees were men; ten were women.

Figure #1: Interviewee demographics*

Primary Geographic /Tribal Affiliation	Highest Degree Attained	Age Range 24-62	Work Sector
(3) West/Pacific (5) Northwest (7) Southwest (2) Midwest (2) Northeast (1) Southeast (1) Northern North America	(8) Ph.D. (5) MS/MA/MBA (7) BS (1) Medical Student	(6) 20's (8) 30's (4) 40's (1) 50's (2) 60's	(1) Government-Industry (2) Government (3) Tribal Government (4) Industry (4) Private business (7) University
<p style="text-align: center;">Discipline</p> (1) Forestry (1) Fish Biology (1) Chemistry (1) Water Resources Management (1) Environmental Science/Hydrology (1) Environmental Engineering (1) Mechanical Engineering (1) Manufacturing Engineering (1) Materials Engineering (3) Electrical Engineering (1) Aerospace Engineering (1) Nuclear Engineering/Physics (2) Mathematics/Mathematical and Computational Sciences (3) Programming/Software Engineering/Computer Science (1) Medicine (1) Small Business Owner/Retail/Entrepreneur			

**Note: Tribal affiliation of interviewees purposely withheld to protect interviewee confidentiality given the small number of Native science professionals from some Tribes or for certain disciplines*

Data collection

Interview questions were developed collaboratively by the team. Interviews were conducted by the first author in-person, lasted approximately two hours each, and were audio-recorded and transcribed. The consent process included detailed explanation of the history and purpose of the project and of the interview as related to the interviewee’s educational and professional experience in STEM. This knowledge of the context for the interview provided a backdrop for the way that interviewees presented their stories and importantly, should therefore be understood as an implicit framework for understanding all quotations used in the discussion of the research presented below. Individual quotations used are from much longer, complex dialogues with the interviewer that were always explicitly framed by the issue of the interviewee’s personal experience in STEM rather than their thoughts on life irrespective of these issues.

Questions were posed in a semi-structured format. Interview questions were open-ended to allow the interviewee to drive the direction of the interview. The interviewer used the interviewee's responses to formulate prompts and follow-up questions. When appropriate in the context of the interview and depending on the content of the interviewee's narrative, concepts from preceding interviews were incorporated into prompts and follow-up questions to engage the interviewee in a discussion of ideas emerging within the context of the interviews. Phase II interview questions were derived from preliminary analysis of Phase I interviews. The workgroup session led by authors #1 and #2 involved exploration and discussion of concepts that were emerging from the analysis of both sets of interviews.

Data analysis

We analyzed 41 lengthy transcripts (21 from Phase I, 19 from Phase II, and 1 from the Workgroup Session). Transcripts were 25 to 55 single-spaced pages each, tending toward the latter, and totaled over 1400 single-spaced pages. In the first round of analysis, transcripts from Phase I were reviewed. The first author identified conceptual categories and patterns related to specified domains of inquiry based on our theoretical understanding of existing ideas about Native Americans in STEM specifically with respect to culture, identity, and cultural interface, and we added new categories and domains that we found to occur in the data. Data were extracted into separate electronic files, and conceptual summaries of the domains were developed. Phase II questions were informed by this initial analysis and by a parallel analysis of AISES scholarship essays that was led by the second and fifth authors. After Phase II interviews were completed, Phase II transcripts were read and reviewed. We used Phase II responses to deepen our understanding of the conceptual categories and patterns related to our preliminary analysis and we refined our categories and domains. The project team met routinely across these phases of the work and reflected on the development of conceptual findings. Feedback was also provided by the Advisory Board. This secondary analysis, including the analysis of scholarship essays and feedback from project meetings, was used to develop the Workgroup Session questions. Following the Workgroup Session, transcripts from Phase I and Phase II interviews and the Workgroup Session were read as one complete data set. We further refined conceptual categories and patterns related to our preliminary and secondary analyses, and we developed conceptual summaries. Using this analysis of the complete data set, we conducted a review of the literature to identify ideas, concepts, and approaches to help us understand what we were seeing in the data, and we identified ways that data from this study and our emerging analysis could address gaps in the literature and/or contribute to theory in relation to the issue of success among Native Americans in STEM and conceptualization of situations of cultural interface.

Following review of the literature, we read the complete data set again and coded for our initial theoretically derived categories, for unanticipated categories that emerged from interviewee narratives, and for categories salient to the existing literature. Coding categories included identity, wayfinding, perspective, giving back, resilience, and Native organizations. Some data were coded into more than one category when appropriate. In this round of coding, data files for each of the six categories were large. To reduce the dataset and produce this

manuscript, we went through a six-stage honing process. First we read the data file in three iterative stages. In each stage, we deleted quotes that were duplicative in meaning or that did not seem as significant or coherent when reviewed in the context of the other quotes in the category, and we “cleaned” quotes to remove identifying data and discursive utterances that did not relate to the intent or meaning of the quote (such as “like,” “you know,” and “umm”). The data file produced in iteration #3 was internally hand-coded for systematic themes and sub-themes. Data related to each theme were extracted and used to create separate electronic files. Each of these files was subjected to a final round of honing, refinement, and reduction. We used “constant comparison” (Perry 2003) to explore interconnections between theme categories and concepts we had identified in the literature by developing a holistic interpretation of the data that we present below.

Thinking conceptually about Native success in STEM

Despite the diversity of the interviewee cohort and the enormous quantity of transcript data, we identified a number of clear key themes in our analysis. Elsewhere we discuss identity (Page-Reeves, et al. 2017a), giving back (Page-Reeves, et al. n.d.-c), cultural resilience, transformation of perspective, and Native organizations. Our purpose in this paper is to build theory about the practices Native Americans in STEM have engaged in as they integrate different dimensions of their lives and “find their way” in the mainstream educational system and the workplace, and the ways they narrate stories of self in relation to this process. Below we develop theory related to concepts of *navigating* and *wayfinding*, which we consider to be identity-forming processes that support resilience. These processes are informed by cultural visions of success based on ideas of giving back and being in relation with others. This is not a path that others have necessarily traversed before (*e.g.*, figuring out how to mesh being a laser scientist or an aerospace engineer with being true to one’s culturally defined values and connecting work and professional expertise to broader purpose(s)).

Figure #2: Thematic Overview

Theme	Subtheme	Sample Quotes
Synthesis and Alignment	Connection Between Personal and Professional Realms	<i>“It is about how you interweave everything together”</i> <i>“You are always both”</i>
	STEM Education Promotes Synthesis and Alignment	<i>“You can bridge cultural identity with an education”</i>
Navigating/Navigating	Adaptation	<i>“Adapting, you know, sometimes you have to be the same and then, slowly you start changing ideas”</i>

	Importance of Social Relations	<i>“The navigation thing is probably the most important—that you learn something about navigating and it helps to cultivate a sense of belonging”</i>
	Developing a cognitive map	<i>“The quicker you’ll learn to navigate and then become your own navigator”</i>
Wayfinding	Interweaving Dynamic Dwelling	<i>“We all are knitting our own piece of fabric”</i>
	Creating Possibilities	<i>“We’re ... a generation that’s kind of defining a new path. We’re melding lots of different aspects of who we are”</i>
	Emergent Perspective	<i>“[The Native STEM professionals I know] are seeing others connect all these different things, and so I’d say the more they develop academically and professionally, the more they begin to see the whole and not just this or that, this or that”</i>
	Experiential Wisdom	<i>“I think ... [pursuing an education and a career in STEM] starts off as to benefit of native people. But then ... the more you work with it and the more mature [you get] ... the more you realize there’s more than just the Native people. There’s ... the whole of science and bettering ... the world”</i>

Using transcript segments from the interviews, we create a sketch of “critical cases” (Patton 2001, p. 236). These cases help to illuminate a theoretical framework that connects navigating and wayfinding while highlighting differences between these two practices. Both navigating and wayfinding support personal journeys and “everyday acts of resurgence” (Cornassel 2012, p. 88) for Native STEM professionals as they traverse mainstream science education institutions and contend with dominant attitudes and ethics in workplace encounters.

We conceptualize *navigating* as following a path that others have laid out and traveled before. At times this involves what Shirin Vossoughi (2011) refers to as the “creative appropriation of cultural tools” (p. 38). Drawing on the work of sociocultural theorists like Barbara Rogoff (2003) and Yrjö Engeström (2007), Vossoughi outlines the ways in which appropriation, as a form of learning, is both individual and collective, as well as transformative. By using and adapting cultural tools (*i.e.*, cognitive maps) from previous generations, transformation occurs at both the individual and collective level. We understand *wayfinding* as a process of transformation that involves using contextual cues in the environmental and experiential field to agentively weave the fabric of one’s life and to create one’s own path in a way that connects with culturally defined values and relationships. Within this context, wayfinding is a complementary/communal practice of integrating emergent life narratives with experience in a manner that aligns with culturally defined values. As we indicated above,

important developmental task on this path is understanding and figuring out one's contribution or how one might give back to the community (Minthorn & Chavez 2014). Here, we are reminded of Stephanie Fryberg's and Hazel Markus' (2003) work on possible selves. They write:

While individuality is not absent, in many American Indian contexts it is understood within the framework of an "other" focus. Suina and Smolkin (1994) highlight this relationship among the Pueblo Indians, "To shine as an individual in the Pueblo world is to have done so on behalf of the extended family and the community; such excellence brings pride and cohesion to the group" (p. 118). Individual achievement is understood to be both an individual and a social project (p. 327).

Similarly, navigating and wayfinding involve relying on cultural wisdom and developing new tools to in order to chart one's path. A path that is both shaped by the individual and simultaneously connected to community.

STEM education: *"a path for our viability"*

Two important dimensions of interviewee's lives are being Native and being part of the STEM professional community. Interviewees think about their work as a synthesis of different cultural perspectives. One person said that the relationship between Western and Native science and the connection between professional and personal realms is the *"overlay of my life."* About being Native and being a STEM professional, others said, *"It is about how you interweave everything together," "You are always both,"* and *"I see both perspectives and I think it has to do with the ability for an individual to synthesize the differences and then find the commonalities ... It's like I think they're actually one and the same."* These ideas of overlay, interweaving, sameness, and synthesis are important in relation to the ability of these individuals to be successful in STEM (Page-Reeves, et al. 2017a).

In our project, one interviewee explicitly identified education as the thing that allowed for this process of interweaving to be played out in his life, saying, *"I think the whole process that you can combine and be within both realms [being Native and being a science professional] is truly what made me where I'm at or allowed me to be where I am at. You can bridge cultural identity with an education."* Another interviewee described his experience: *"I feel like for myself and so many of my peers that... our experience [getting a science education and working as STEM professionals], it's like we're a generation that is kind of defining a new path. We're melding lots of different aspects of who we are."* This idea of actively using western education to *"define a new path"* and *"meld different aspects"* of one's identity, captures something essential and important for understanding success among Native Americans in STEM.

In her study of space, identity, and scientific discourse among Indigenous women in higher education, Carol Brandt (2008) describes how the women she spoke with created "locations of possibility" where their indigenous and scientific identities were able to be aligned. Similarly, in our data, through the experience of finding a path for themselves within the context of the dominant science education system, Native STEM professionals are creating new spaces for being Native. One interviewee described it as *"those who have some insight and some knowledge*

and understanding that education is the path for our viability, our, our sustainability.” Yet, the process is not a clear one, nor is it easy, as was illustrated by the comment of one interviewee that,

My parent’s generation, since they were the ones that experienced the whole turmoil with school ... they wanted better for us ... the whole message is, “yeah, you need to go get an education” ... [but] they can’t guide us along that path, because a lot of them haven’t been through that path, they haven’t gone to higher education or gotten a Master’s or PhD’s ... they just say, “just go out there and do something. Get an education and then come back and do something with it.” So it’s very open ended, and it’s something that I feel like ... me and all my peers [in STEM] ... we’ve always had to try to figure that out... like what do we do? ... I don’t know, like how are we going to use this education? It’s like I have no idea.

We propose that navigating and wayfinding, two inter-related processes, support Native STEM professionals as they engage with this challenge to complete their educational studies, find their path, and determine how to put their education to use.

Navigating as cognitive mapping in the process of STEM education and professional development

Interviewees referred to the process of surviving rigorous science course work, getting a degree in STEM, and becoming a STEM professional as “*learning to navigate*” and “*finding a voice.*” This developmental perspective is echoed in Na’ilah Suad Nasir and colleagues’ (2006) discussion of learning as a cultural process. They describe navigating across contexts and settings as “the development of flexible knowledge and dispositions” (p. 490). Similarly, Diane Austin (1998) suggests that this type of adaptive change reflects the development of a cognitive map. “Cognitive maps include physical attributes of a place, stories about it, and information about how to behave in it” (p. 21), and are rooted in a cultural milieu. These conceptualizations of navigating fit with what emerges from our data.

The vast majority of interviewees described experiences of “*learning to navigate*” myriad social, educational, and institutional processes and contexts as being key to their success. Navigating was described as learning how to apply to college, developing good study habits and time management skills, understanding and knowing what are the general rules of operation in a college setting, grasping what it means to go on to graduate school, and getting a job after completing a degree. They also emphasized the importance of adapting and being flexible, and saw this as an inherent quality of Native communities:

adapting, you know, sometimes you have to be the same and then, slowly you start changing ideas ... changing ideas and educating people is something that ... takes years, and it takes months, weeks ... it takes a long time for people to change.

Additionally, speaking about his success in STEM, one interviewee said, “*success really depends on how one is able to utilize resources.*” Knowledge of resources is a key component of

navigation because interviewees repeatedly described how they were often just completely unaware of what resources were available to them—before going to college, while in college, and after graduating.

The social dimension of navigation is also crucial. Navigation is understood by interviewees as relational. Navigating involves finding people (both Native and non-Native) who you can relate to, who share your experience, and who can help to support you (and vice versa). Interviewees recounted stories of this from grade school, high school, college, graduate school, and the workplace. Navigating is learning who to go to for help, who has knowledge or capacity that you do not have yourself, and how to tie yourself to people who can help you now or in the future. Angela Calabrese Barton (2003) and Brandt (2008) discuss how this sort of social capital allows for “co-opting” social space within hegemonic environments as a way to get access to resources that would otherwise be tethered to class privilege in an exclusionary way. One interviewee emphasized this social-spatial dimension of navigation as networking. He said, “*the navigation thing is probably the most important—that you learn something about navigating and it helps to cultivate a sense of belonging.*” Knowing how to navigate and networking with others contributed to interviewees’ sense that they belong in the STEM educational and professional milieu and gave them self-confidence. Another framed the personal and social connectedness component of navigating as important in developing strategies for confronting challenges or failures, saying, “*the truth is you always have a hundred cheerleaders for every three terrible people, if you [only] look for them.*” But the process of navigating or learning to navigate is also transformative. One interviewee described navigating in relation to his experience of figuring out how to succeed in math and engineering classes that he found to be very difficult as,

having a network of people to tell you here’s what you don’t know in a graceful and meaningful way ... the part that helps an individual build confidence. And the more you can expose yourself to those types of people, the quicker you’ll learn to navigate and then become your own navigator.

In this way, navigating is about learning from already explored paths and agentively integrating this knowledge into personal conceptual repertoires.

For interviewees, succeeding in the mainstream science classroom and becoming a STEM professional involved the development of a cognitive map that connects their ongoing experience in STEM with their personal identity as a Native person within a context of belonging—they understand navigating to have a relational dimension, and they connect the act of navigating to achieving culturally and spiritually defined goals. But this process is also challenging. One interviewee described it as,

I feel like part of being able to navigate in a way that we feel good about it is the context—understanding the relevance ... We have it in our mindset that here is what I have a sense of. I’m going to do this, and then I’m going to come back and play this role [as a STEM professional] in my community ... it’s important for us to be able to understand or have a context for how this is going to play out. I think that is one of the

missing pieces for a lot of us coming from traditional communities, is that we have a sense that this Western education is important, but we can't envision how we are going to plug in.

We see in our data that this process of creating a cognitive map for *becoming a scientist* is not passive—it has a significant agentic quality reflected in the active phrasing of “*finding a voice*” and “*learning to navigate*.” Interviewees are navigating but with an eye to not just passing through the mainstream educational system to become academics or engineers or Intel workers—they want to figure out how to make their experiences, lives, and careers intersect meaningfully with culturally defined motivations, values, and purpose (Page-Reeves, et al. n.d.-c). They struggle with this, but they have been in the process of figuring it out. They are actively constructing their lives in the mundane, everyday sense, but also with a long-term vision. Another interviewee, speaking about the responsibility of individuals who obtain degrees in STEM framed this process even more boldly,

Now the onus now lies on individuals ... we can't go back and blame ... history. The destiny is within our hands. So the onus is on us to actually make things happen. So in that sense, it's really ... seeing it to fruition, what we believe our destiny is and... following a path. And our ancestors have been fighting for ... decades, centuries, to get to the point we're at today and I think we're at the pinnacle ... at the ... inflexion point.

We see this dynamic, agentic process of discovering and creating that “*inflexion point*” as wayfinding.

Wayfinding in STEM

In the academic literature, the concept of wayfinding generally describes how individuals use environmental cues to chart a course, most often for moving through a physical space (Katoaka 2013). Wayfinding is used in discussions of community planning (Vandenberg 2013), engineering design (Edelman and Leifer 2012), institutional design such as that for universities (Moldenhauer 2015) or health care facilities (Carlson and Bose 2015), challenges faced by older adults in negotiating community environments (Marquez, et al. 2015), mentoring through personal stories of finding one's way (Weeks, et al. 2012), strategy research (Spiller 2012), and even organizational management where it is associated with the concept of “strategic foresight” (Sarpong, Maclean, and Alexander 2013). Drawing on knowledge gained from studies with Indigenous peoples, Tim Ingold (2000) describes wayfinding as being akin to storytelling and mapping. In this framework, wayfinding involves using prior experiences that are grounded in perception and action to feel one's way toward a goal. Wayfinding is a process of following a path that emerges from interaction with the environment and “learning as you go” (Ingold 2000). In this case, wayfinding also has the dimension of being a type of wisdom grounded in collective past experience that creates resourcefulness.

Chellie Spiller (2012, p. 63) suggests that standard processes of navigation can only follow “routes that others have traveled—only the knowable.” While navigation “involves a

predetermined plan of what and how” (Edelman and Leifer 2012, p. 153), wayfinding relies on developing capacity to perceive nuances of context and integrate multidimensional information into meaningful action. Spiller (2012) calls this “dynamic dwelling” (p. 84), meaning that wayfinding “emphasizes a responsive, detailed and disciplined engagement with an unfolding and continuously changing environment” (p. 62). Such active engagement in defining one’s own journey or destiny is a type of “dynamic dwelling” (Spiller 2012, p. 84) that is a part of interviewees’ narratives of their experience in STEM. This process of dynamic dwelling becomes part of both an individual’s self-concept and more broadly contributes to the success of the community. One interviewee expressed that his success as a STEM professional had been “*a slow, methodical process and it’s ... an accumulation process ... it’s just a matter of aligning people and purpose to accomplish what one might call success.*” Another, speaking about her experience being the only Native person in a graduate math program at an elite university, and the only Native person she had ever known who had obtained a similar degree said, “*you become part of the fabric. I think everybody that comes in contact with you during your life becomes part of your fabric ... we all are knitting our own piece of fabric.*”

Theoretical conceptualizations of wayfinding are apropos for understanding the narratives that emerge from stories of Native STEM professionals whose experience is in historically white science educational systems and in STEM careers. Borrowing ideas about wayfinding from various disciplines and contexts also moves us beyond problematic conceptualizations of cultural encounter based on bi-cultural domains, distinct but intersecting cultural “worlds,” and the seemingly inevitable formulation of cultural hierarchy that are commonly involved in discussions of Native Americans. We see wayfinding as a useful way to think about the experience of learning to operate in a context involving plural cultural frameworks. The interviewees’ narratives of their experiences with STEM gathered as part of this study do just that—they demonstrate how wayfinding becomes a mechanism for interviewees to interweave accumulated experience in mainstream science education and in STEM professions to create a new story, one in which the ending has not yet been written. Interviewees discussed the challenge of finding meaning in their success in STEM saying, “*I’m still in the process of ... figuring it all out,*” and,

I don’t feel like I’m fulfilled yet [by my educational and professional success in STEM], I’m in the process of fulfilling, but I think there’s many more things I wanna do ... it’s just a matter of timing and stages, there’s stages of life I guess, and ... I feel like I’m still finding my footholds in my life and this is like a holding place ... I think there’s something greater in store for me and I feel like I still haven’t defined [it] ... where I’m at now as a place of success. There’s little successes, milestones, but I haven’t [reached an end].

Wayfinding, agentive emergence and experiential wisdom

In his thoughtful article, “Indigenous knowledge, indigenous scholars, and narrating scientific selves: ‘to produce a human being’” in *Cultural Studies of Science Education*, Michael Marker

(2015) suggests that “ways of thinking become ways of being.” This philosophical stance is illustrated in quotes from interviewee narratives presented above. In our analysis of these data, consideration of Marker’s comment suggested to us that something interesting is happening in the stories described by interviewees. There is something key happening to interviewees in relation to the experience of passing through the mainstream science education system and pursuing a profession in STEM. At the same time that interviewees are in learning environments in historically white and Western-defined STEM educational contexts and becoming STEM professionals trained in Western epistemological approaches, they are deeply embracing their indigenous selves (Page-Reeves, et al. 2017a). Common ideas about cultural interface such as acculturation (e.g., Choney, Berryhill-Paapke, and Robbins 1995), bi-culturalism (e.g, Huynh, Nguyen and Benet Martinez 2011), multiculturalism (e.g., Bradley 2013), or cosmopolitanism (e.g., Beck and Sznajder 2006) do not fully capture the dynamics of this process as described by the interviewees.

Similar to the way that Terry Huffman (2010) conceptualizes transculturation, we believe our data demonstrate an *emergent* sort of change that is occurring. This emergent quality is key because what is happening is not just an admixture of cultures or identities, but something that is more than the sum of its parts. Interviewees did not describe a new culture or suggest that they have left behind their culture; their new state is unique without erasing previous personal and cultural identity frameworks that continue to be relevant in their lives. We suggest that the process of wayfinding supports such “emergent lifeways” (Coombes, Johnson and Howitt 2012, p. 692) or “emergent capability” (Spiller 2012, p. 63). Interviewees have a new way of *being in, engaging with, and experiencing* the world. Our approach emphasizes the agentic nature of people in the process rather than a depersonalized culture as a delimiting domain *per se*. This is an important distinction for theorizing about contexts involving plural cultural interface.

To develop our theory of wayfinding, we look to the organizational management literature, where, interestingly, David Sarpong, Mairi Maclean, and Elizabeth Alexander (2013) describe similar dynamics in their conceptualization of wayfinding as “strategic foresight.” They write that developing competence in the day-to-day social practice of organizational activity is “an actualization of a continuous process of becoming [in which wayfinding is] a generative and iterative organizing practice whose coming to presence is internally emergent and negotiated rather than externally brokered” (p. 34). Wayfinding requires “intelligibly challenging those constraints imposed by social structures and individuals’ taken-for-granted assumptions about reality ... the ongoing, collective, deliberate and conscious locally reflexive orders of actions engaged in by organizational members that underpin the perception, reproduction and transformation of their social structures” (p. 37). We find much relevance in this formulation for thinking about our data. For wayfinding among Native STEM professionals, the interviewee quoted above who said, “*I feel like for myself and so many of my peers ... our experience [in mainstream STEM education and as STEM professionals], it’s like we’re ... a generation that’s kind of defining a new path. We’re melding lots of different aspects of who we are,*” expressed it as,

for me, personally, it hasn't come easily ... I've experienced a lot of ... internal conflict about my path [as a computer science major in college and then working as a STEM professional in industry] ... over the years. And... I've come to a point at almost 50 years old that ... I feel like I'm finally starting to reconcile all of the pieces of my life, where I've come from, what I've learned professionally, what I've done in the world, and where I'm going.

What our data add to the conceptualization of wayfinding is a Native experiential perspective—that this new state of being contains a blueprint for something defined by Native cultural values but with broader social and cultural connections, something that for most of the interviewees is still in the process of being embodied.

Greg Cajete (paraphrased in Marker 2015) said that differing knowledge systems must “find a pedagogy of holism combining the best of both—a third space to merge Indigenous knowledge and western scientific thinking” (p. 3) as a key to building capacity for tribal sovereignty. We suggest that identification of people in that space must precede its description—which is what we are seeing in our data. Marker (2015) writes,

Beginning to think this holistic way about reality/science can soften and dissolve the concrete walls between the categories that enforce dangerous binaries in our present world. Such a move toward this holistic mind also implicitly *re-purposes* both science and education more broadly” [emphasis in original] (p. 3).

Considering Marker’s comments in relation to our data, we believe that this sense of an emergent state of being that comes out in the interviewees’ narratives is something that many people (Native and non-Native) experience with higher education or with life-altering experiences such as parenting, dealing with death or permanent disability of a family member, living abroad, or going to war. These experiences provide not only content knowledge about a particular issue, context, or activity, but also a transformation of perspective. One interviewee described it as, “[the Native STEM professionals I know] are seeing others connect all these different things, and so I’d say the more they develop academically and professionally, the more they begin to see the whole and not just this or that, this or that.” The reality is that through experience in mainstream STEM education and careers, interviewees are changing—changing the way they view themselves (their identity), changing the way they view their communities and the people in their communities (their perspective), and changing their way of thinking about and being in the world—and it is more than just being educated. Interviewees told us things like,

[Those of us who chose to be in the sciences] wanna do good things, we wanna help people ... it's kind of who we are and we wanna be able to give back and go back and help our communities. It is a hard thing to understand how going into Physics is ever going to help anyone, but the thing is ... I think it's completely possible to do something that inspires you or that you like to do and then also be able to take those tool sets and...and be able to...go back and help your tribe.

And,

I'm happy that ... I've been able to apply my collective knowledge [from my education and as a STEM professional], not just ... the credentialed knowledge ... but the skills that I've learned in life. And for me, the other important piece, I would not have been successful as a [tribal government official] here if I didn't know my knowledge, my culture, and shored up by my professional background [in STEM and explicitly having worked as a STEM professional in industry], knowledge and skills that I've learned outside that I brought back, applying all of those together, again in a connected way. I've been able to do the things that we need ... without compromising the culture or in any way taking us away from what we value as a community. So from that standpoint ... I have to give some credit to my formal learning and the learning that I received ... to help me move this community forward.

These quotes get at the heart of the elusive, emergent quality of the change that is occurring. Calabrese Barton (2003) and Brandt (2008, p. 717) discuss how through the experience of higher education, individuals adapt and transform practices that enhance their sense of self through an additive process. In our data, we see that transformational personal experience is accumulated iteratively over time, allowing interviewees to develop strategies and new perspectives to dialectically (re)connect their lives and work with the culturally defined *purpose* of giving back (Page-Reeves, et al. n.d.-c).

We situate this accumulation of knowledge through experience in the Native wayfinding tradition by identifying it as what we call *experiential wisdom*. Per Amy Klemm Verbos and Maria Humphries (2014, p. 3), we see wisdom as a foundational component of a Native relational ethic. Specifically, the wisdom that interviewees are demonstrating has to do with seeing themselves and their possible selves in a more interwoven and expansive way. One interviewee said,

I think ... [pursuing an education and a career in STEM] starts off as to benefit of native people. But then ... the more you work with it and the more mature [you get] ... the more you realize there's more than just the Native people. There's ... the whole of science and bettering ... the world,

Another said,

I think...you definitely first think about giving back to the Native communities. Some people don't ever picture the whole scheme of things. But ... the more you think about it...the more you immerse yourself in your work [in STEM] and study literature and figure out what you're doing and why you're doing this, you see that there is a much greater picture, and you can have a meaningful impact on how ... things are, and not just with your family, your people, but just in science.

Yet another believes that it is about

the foresight and wherewithal to understand that [through your studies and work in STEM] you're not just impacting yourself but for generations to come. And in that sense, it's a sacred responsibility and it doesn't have to be a direct spiritual connection but just you understand that ... you're not only impacting within your domain but domains outside ... It takes a process to get to that point.

This expression of experiential wisdom is one of the things we are capturing in our research. It is different from the experience being discussed in the broader literature on cultural interface—it is an experience that involves a feeling of, creation of, elaboration of *interconnectedness*—with Native community and values, but at the same time, also beyond more broadly to science as a domain of knowledge and to other peoples of the world.

Composing “*the inflexion point*”

Our exploration of interviewee narratives disclosed personal journeys that are iterative, reflexive, and dialectic. Their stories reveal important insights for understanding dynamics of the experience of Native individuals who have been successful in STEM in a context without culturally responsive or sensitive pedagogy. Despite strong evidence that culturally based epistemological orientations in the classroom and in the educational curriculum make an enormous difference for Native students, the mainstream educational system continues to be the primary educational framework for Native students, and as we all know, change is slow. As such, the stories explored here provide important insights for thinking about experiences and trajectories of Native Americans who have made the sometimes difficult choice to pursue an education and career in STEM within the “powered context” of the “[racialized] hierarchies that permeate science education” (McGinty and Bang 2016, p. 471). It is, of course, essential to continue exploration of pedagogical approaches such as CRS, CSS, ISE, CSRP, and IAS, and to advocate for policies at all levels of the educational system to enact consistent, well-grounded curricular changes and epistemic adaptations to support Native students who are interested in STEM and to nurture interest in science among Native youth. But it is also important that we consider the stories and honor the experiences of Native STEM professionals who have had to make their way through the existing system by activating their own lived experience of Indigenous knowledge(s) (Brayboy and Castagno 2008b), and who, in the process, are creating something valuable, optimistic, and authentic. The paths they are traversing as they navigate and find their way (wayfind) makes an important contribution to community dynamics that support tribal sovereignty.

Our interpretation of data from interviewee narratives proposes a novel and nuanced theoretical conceptualization of cultural dynamics with import for considering cultural interface more broadly. Despite the challenges, Native Americans are gaining new ground as science professionals, challenging socially constructed boundaries that have previously limited educational choices and career trajectories for Native people. They are actively creating new opportunities for themselves and forging new paths for others that expand spaces for Natives in STEM (*wayfinding*). They are defining their own way to participate in science, but in the

process, they are constructing distinct knowledge derived from experience (*experiential wisdom*) and creating new and generative ways of engaging with the world that redefine the nature of the interface between Native and non-Native culture. We call the outcome of this process *cultural perspicacity* (Page-Reeves, et al. n.d.-e), a concept which we are exploring in our ongoing work on Native success in STEM.

Interviewees discussed the idea of “*walking in two worlds*” that is often used to describe the dynamics of Native American experience, but in general they disavowed or strongly rejected this metaphorical description of their own experience (Page-Reeves, et al. 2017a). Writing about Native Hawaiian culture, Rebecca Hogue (2013: 79) proposes that “binaries ... have long been incorporated into academic discourse, and more recently, [there has been a] growing shift toward subverting, flipping or inverting them,” but that “dichotomous structures ... are losing relevance in a globalized world where the lines ... are substantially blurred and may no longer exist.” We see this in the interviewee narratives that we gathered through this research. As individuals, interviewees are engaged in “anti-colonial projects” (Coombes, Johnson and Howitt 2012: 691) that challenge and contradict dichotomies by the very nature of their pursuits in STEM and in professional and discipline-specific spaces of science. Yet in general, while interviewees recognize themselves as trailblazers for others in the Native community (Page-Reeves, et al. n.d.-c), they do not see themselves as antagonists or frame their stories as adversarial. Not everyone embraces being a resister (Page-Reeves and Cardiel 2016). Part of being co-opted and dominated by an oppressive system is having to live your life embattled. Interviewees have rejected this in the way that they are engaging with the world through holistic and interwoven pathways that connect with their own Indigenous identities and cultures while creating roots of interconnection with broader social and cultural realms. Brandt (2008) describes how Native women in her study have developed discursive practices and spaces that create the possibility of engaging in a positive way with their educational experience. These spaces “[offer] an alternative to the toxic effects of objectification” (Brandt 2008 p. 719) that are too often part of everyday life for Native people in the mainstream educational system. Similarly, in our data, interviewees demonstrate how they are “[dynamically] dwelling” (Spiller 2012) in the lived experience of their own indigenous knowledge(s) (Brayboy and Castagno 2008b). They are *doing* resistance and desettling (Bang, et al. 2013) in their own way through the everyday, quotidian activity of pursuing a science education, getting a degree in STEM, becoming a science professional, and learning how to translate their knowledge and experience into meaningful action in their community and in the world.

Expanding fields of action for Natives in STEM are creating a positive environment for learning and growth that is providing skill sets, knowledge, experience, perspectives, and wisdom to bolster the foundations of Indigenous sovereignty. Brant (2008, p. 719) suggests that “by creating discursive spaces in which narratives can be shared...scientific discourse becomes expansive rather than narrow, boundless instead of limited and inclusive rather than exclusionary.” Brad Coombes, Jay T. Johnson and Richard Howitt (2012, p. 692) portray the wide range of expanding fields of action for Native Americans in multiple domains as a process

characterized by “optimism and prototypes for geographies of hope.” Al Qöyawayma (Hopi), an AISES founder, described “the spirit of that first [AISES] meeting [as] one of hope” (AISES 1985, p. 3). Our research demonstrates that despite the limitations of mainstream science pedagogical practices and the challenges of working in the “powered contexts” (McGinty and Bang 2016, p. 471) of STEM careers, Native science professionals are actively constructing what one of the interviewees quoted above called the “*inflection point*” that is transforming the reality of possibility for Native Americans and fabricating a positive, generative landscape for the concrete and everyday embodiment of that hope which, in the passionate words of one interviewee, is “*so overwhelmingly wonderful, positive.*”

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