GEOCONNECTIONS: THE IMPACTS OF GEOSCIENCE EDUCATION INFORMED BY INDIGENOUS RESEARCH FRAMEWORKS

by

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I wish to dedicate this work to my family. My parents and their ever-loving support and perseverance has inspired me to keep achieving. My sisters and brothers have also encouraged me and lifted me when I needed it most. Thank you all!

I would not be here without my Ancestors and so I also dedicate this work to those Indigenous relatives who made a place for me in this world. I can only hope that my work will honor their sacrifices and create pathways for future generations to transform the world around them into something useful and good.

Duu shiino'meh Shuu'dti Mutd'th d'at eh sh'esh,
Ba-ba Mii'titsa eh tseh' wah hou'rh sha'wiit'ta'a eh tseh tsii' nuu'shru meh'tsrh'trneh'sheh eh tse noh'druu'mih tsi howh'ween'ah
Bah'gai'meh'eh du'maa'tsi'ni'hih howh-bah
Ah'muu nay'atrh'th dru'mah, ah'muu nii'trh' duu'mah, Ba-ba
Gai'meh'eh nu'mah dst'eh, Stsah'nee'duu ushraath'th duu'ku mah'nii Yu'nah buu'ni-ya tsuni-ya tzuu'sth
Gai'meh'eh nuu'mah'ntsi duu'mah, Eh'meh'eh tsu'tsah' nah'du'meh'trsth'eh d'aii Shuu'dti eh sh'esh
Bah'dtu'mah'tuh'nee
Gai'meh'eh ah'muu nii'trh duu'mah

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ABSTRACT

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All of the work described in this dissertation involves the use of Indigenous research frameworks to design research projects, to facilitate communication with Indigenous communities that I have collaborated with, and also to teach and mentor undergraduate and graduate students. Indigenous research frameworks emphasize the importance of place in relation to the integrity of cultural values espoused by many Indigenous communities. This entails a respect for the spirituality component of Indigenous people because this is often directly tied to relationships between the land, animals, and plants of their local environments.

While some research has been conducted to help understand Indigenous people's understandings of geoscience, less emphasis has been placed on recognizing and leveraging common connections Indigenous students make between their Traditional cultures and Western science. Thus, the research presented in this dissertation identifies connections Indigenous learners make between geology concepts and their everyday lives and cultural traditions in both formal and informal settings. Some of these connections have been integrated into place-based geoscience education modules that were implemented within an introductory environmental science course.

Qualitative analysis, using a socioTransformative constructivism theoretical lens, of semi-structured interviews after implementation of a Sharing/Learning program for an Acoma pilot project, implemented informally, and for a series of geoscience education modules at a private university provides evidence that elements reflective of the use of sociotransformative constructivism (e.g. connections between global and localized environmental issues) were acknowledged by the participants as particularly impactful to their experience during implementation of the geoscience-focused activities. In addition to the socioTransformative theoretical perspective, Indigenous research frameworks (i.e. Tribal Critical Race Theory) were used to contextualize the educational interventions for two different Indigenous communities,

Acoma Pueblo and the Confederated Tribes and Bands of the Yakama Nation. Tribal Critical Race Theory was not used to analyze the semi-structured interviews. Instead the Indigenous research frameworks were used to ensure that the research practices undertaken within these Indigenous communities were respectful of the Indigenous community's cultural values, that Indigenous data sovereignty was paramount, and so that the research objectives were transparent. In addition, permission to publish the results of this research was sought from the governing entities of both Tribal Councils of Acoma Pueblo and the Yakama Nation.

The impacts of using socioTransformative constructivism and Indigenous research frameworks to implement the Acoma Pueblo pilot project resulted in the privileging of the Indigenous perspectives. This was made evident by the sharing of Traditional knowledge about Acoma culture and history throughout the entire Sharing/Learning program. Also, during a group discussion at the end of the Sharing/Learning program, Acoma Pueblo Elders utilized their power to define the connections they made between geology and their cultural knowledge for themselves, and in their own words. The holistic approach of the Sharing/Learning program included inviting Acoma Pueblo community members of all ages to participate. This served the interests of the Acoma Pueblo community because one of their primary cultural values is the sharing of cultural knowledge within an intergenerational framework. The Sharing/Learning program met this objective.

The impacts of using socioTransformative constructivism and Indigenous research frameworks to implement the GeoConnections project resulted in the participants exhibiting metacognitive and reflexivity when questioned about how the geoscience education modules impacted their perceptions of geology and geoscience. One participant was able to connect similarities between local and global environmental protection efforts by using reflexive thinking practices. Another participant made a connection between their English major's pedagogical values and the values of geoscience researchers: they are both focused on sharing knowledge with others. Many of the participants also gained a more critical perspective of the local agricultural industry and its environmental practices. The participants expressed this critical perspective by connecting these practices to the potential impacts on their individual as well as their community's health.

The research presented in this dissertation provides evidence that academic research can be undertaken in respectful ways that benefit Indigenous communities. The connections that

participants in the Acoma Sharing/Learning program could potentially be used to create more culturally relevant educational materials for the Acoma Pueblo community, if that is what the governing entities of the Acoma Pueblo community desire. The modules implemented more formally at a private university could potentially, with permission from the governing entities of the Yakama Nation, be integrated into geoscience programs at a broader level creating opportunities for contemporary Indigenous perspectives to be valued alongside Western modern science. Moving forward, this could potentially increase interest among Indigenous community members in pursuing academic pathways within geoscience disciplines.

The research pursued in this dissertation is only a beginning. Approaches to research that promote the agency of local communities in the types of research questions asked and how that research is conducted should be a priority for Western scientists to maintain a respectful relationship with the many communities, Indigenous and non-Indigenous, in which they work. It is my intention to be part of this revolution in how academic researchers interact with contemporary Indigenous communities as well as the next generation of scientists. In the future, my research will continue to serve and benefit Indigenous communities, but I will also begin asking research questions that will help increase the use of diverse and equitable practices within academia. In this way, I hope to bridge the two worlds of Indigenous Knowledge systems and Western science with the primary purpose of maintaining respect among these two communities. In the future, my research will focus on how these respectful practices can move beyond academic research and pedagogy into the realms of professional development, mentoring, and community revitalization.

INTRODUCTION

Coming from one of the oldest continually inhabited communities in North America, Acoma Pueblo, NM, my educational experiences have been shaped by deep ties to my home community. All of the work described in this dissertation involves the use of Indigenous research frameworks to design research projects, to facilitate communication with Indigenous communities that I have collaborated with, and also to teach and mentor undergraduate and graduate students. Indigenous research frameworks emphasize the importance of place in relation to the integrity of cultural values espoused by many Indigenous communities. This entails a respect for the spirituality component of Indigenous people because this is often directly tied to relationships between the land, animals, and plants of their local environments (Smith, 1999; Cajete, 2000; Brayboy, 2005; Wilson, 2008; Masta, 2018). I have chosen to write this dissertation in a three-paper format, meaning that each major chapter (Chapters 2, 3, and 4) can stand alone and will later be submitted for publication in peer-reviewed journals. Potential journals that these chapters will be submitted to include: *The Journal of Geoscience Education*, *Geosphere*, the *Journal of American Indian Higher Education*, and *The Qualitative Report*.

Perspectives on Terminology

Indigenous Identities

The terms Native American, American Indian, Indian, Native, Aboriginal, Indigenous, and First Nations for many people have clear and separate meanings for many people (Rodriguez, 1998; Smith, 1999). What those meanings are to you, the reader, most likely reflects where you grew up, your cultural upbringing, as well as influences from those people you have trusted enough to discuss these topics. Growing up on the Acoma Reservation in New Mexico the term I am most familiar with is Native American. That was the designated choice for me as I eagerly filled the white bubble with the beautiful, dark markings of graphite. I was taught to be proud of my heritage, ***Ako-meh***. Filling in that bubble was an expression of my heritage and identity and I came to associate myself with that term, Native American.

Moving forward in my academic career and reading the work of Indigenous scholars from around the world, it seems that there is a need for a unifying term that can be used strategically in

a way that serves the interests of Indigenous peoples and their communities on a broad, global scale. Smith (1999) discusses how unifying terms are used in different contexts for various reasons (e.g. Maori, *tangata whenua*, 'People of the Land'). I am satisfied that the way Smith (1999) uses the term Indigenous peoples has enabled "communities and peoples to come together, transcending their own colonized contexts and experiences, in order to learn, share, plan, organize and struggle collectively for self-determination on the global and local stages". For these reasons, for now, I have chosen to use the term Indigenous as a descriptive term within this text. However, at every appropriate opportunity I also choose to use the specific name for particular Indigenous communities.

Indigenous Elders

Indigenous Elders are integral parts of many Indigenous communities because of their lived experience, their roles as knowledge bearers, and their wisdom in navigating the world. However, not all Indigenous Elders keep the same precise relationships within their home communities because every Indigenous community has a unique understanding of what characteristics an Elder should have and embody. Furthermore, these understandings change and develop over time as Indigenous communities continue to thrive in contemporary society. The following description of Indigenous Elders that may provide insight for those not familiar with the concept:

> *"Age does not denote Eldership. There are no application forms posted when a certain age is reached. People are observed and their activities noted in much the same fashion as when children are undergoing their transition to maturity. Later in life when it is felt that their minds are receptive to understanding their role in adult society, they will be invited to become a member of the Elders group not an Elder in their own individual right but for what they can contribute to society as a group."*
>
> **--Uncle Bob Anderson, Quandamooka, Ngugi Elder**
>
> (Martin & Mirraboopa, 2003)

I have not reached status as an Elder in my community, nor do I know if I ever will. With this in mind, I feel a heavy burden in trying to clarify how Elders are recognized within Indigenous communities. The best advice I could give someone who would like to know how to define an Elder is to "Go! Be around them and you will understand." Without this experiential component of interacting and forming a relationship with Elders, any definition or categorization is bereft of completeness.

Relationships Between Geology and Indigenous Communities

Geologic materials and their cultural uses have been part of Indigenous knowledge systems since time immemorial. However, Indigenous knowledge is not always shared freely with non-Indigenous scientists. This disjointed understanding has inspired academic efforts to explore the intersection between Indigenous knowledge regarding geology and geoscience in its cultural context (Cajete, 1994; Morton & Gawboy, 2000; Snively & Corsiglia, 2001; Gibson & Puniwai, 2006; Chinn, 2008; Garcia, 2018). These multidisciplinary explorations have undergone many name changes, including: Traditional Ecological Knowledge (TEK), Traditional Knowledge, Traditional Environmental Knowledge, Indigenous Science, Native science, Indigenous ways of knowing, cultural geology, and ethnogeology. As highly trained (from a Western perspective) Indigenous scholars emerge from their home communities and matriculate through higher education institutions, there has been increased access to Indigenous perspectives of geology and geoscientific concepts (David-Chavez & Gavin, 2018). However, tension grounded in epistemological differences between Western scientific thinking and Indigenous knowledge systems continues to deny an equitable sharing of knowledge in which the benefits of each system are valued and appreciated (Smith, 1999; Snively & Corsiglia, 2001; Cajete, 2008; Wilson, 2008; Hikuroa et al., 2011; Atwater et al., 2014).

Historically, tensions between Indigenous communities and non-Indigenous colonizers have resulted in the genocide and continued marginalization of contemporary Indigenous communities (Smith, 1999; Zywicki, 2013). Specifically, in my community at Acoma Pueblo, hundreds of people were murdered, enslaved, and maimed during colonization efforts (Minge, 1991). These horrific atrocities are still part of the cultural knowledge passed down in my community about the dangers of outsiders and their potential motives. At the same time, Acoma is a contemporary society, firmly embedded within the sociopolitical context of the United States.

Similar to many other Indigenous communities around the world, Elders and other respected leaders from Indigenous societal frameworks have encouraged learning the knowledge offered by non-Indigenous peoples as a way to survive and persist into the future.

Wilson (2008) synthesizes the work of various authors who have formalized "a chronology of aboriginal research" that these efforts to understand non-Indigenous epistemologies represent. Zywicki (2013) provides a more detailed synopsis of the impacts of U.S. policy on "American Indian education" including the loss of culture, language, and the forced removal of Indigenous children from their families to attend boarding schools. These stark truths cast a shadow on the current relationships between Western science and Indigenous communities. However, this is where myself and other Indigenous scholars are now coming into power as part of Martin's (2003; as cited in Wilson, 2008) "Indigenist Research Phase". It is my objective to be a positive influence on the future of education among Indigenous peoples, even as a participant in Western science.

Research Questions and Objectives

This research was initiated with the intent to merge Indigenous Knowledge with Western science. This was before I became aware of Indigenous research frameworks and the power they lend academic research to benefit Indigenous communities. As I moved forward in my academic progress, the research questions I have chosen to explore focused much more directly on privileging Indigenous perspectives regarding geoscience, earth materials, and the trust needed to align efforts between Indigenous and non-Indigenous stakeholders to implement research within Indigenous communities.

Two of the major projects (Chapter 2 and Chapter 3) discussed in this dissertation were approached using a mixed methods design. Specifically, a sequential transformative design was used guide the development of research questions and data collection. The third project (Chapter 4) is an autoethnography. The overarching research question that the research projects in this dissertation seek to answer is "How can Indigenous Knowledge systems and Western science knowledge systems be aligned to produce research objectives that are implemented in culturally sensitive ways?" From this perspective, neither knowledge system is valued as better or more truthful than the other. There is value in both knowledge systems and both have informed the three research contexts provided within this dissertation. However, I no longer feel the need to "merge"

the two knowledge systems into a single entity. Instead, each knowledge system can be used separately or in conjunction with each other depending on the context and objective.

Because research involving Indigenous communities within the geoscience discipline has been approached from a more programmatic sensibility, I have chosen to use exploratory research questions that may help future geoscience programs begin their development from a more holistic understanding of the types of connections that Indigenous community members make between geologic knowledge and culturally understandings of their environment. This approach to research requires specificity. Hopefully this approach will curtail overeager geologists and geoscientists from assuming that cultural connections from one Indigenous community will transfer directly to other Indigenous communities. Instead, I see potential for new research projects with Indigenous and non-Indigenous stakeholders working collaboratively to enhance both Indigenous knowledge and Western scientific knowledge, with each system producing new, unique understandings of the mysterious and powerful world that surrounds us.

socioTransformative constructivism and Tribal Critical Race Theory

Two theoretical perspectives are used throughout the research presented in this dissertation: the socioTransformative constructivism (sTc) framework (Rodriguez, 1998) and Tribal Critical Race Theory (TribCrit) (Brayboy, 2005). The sTc framework acknowledges that knowledge is socially constructed and influenced by cultural, historical, and institutional contexts (Rodriguez, 1998). sTc also creates a way for participants to engage in meaningful dialogue concerning their local communities (Rodriguez & Berryman, 2002; Zozakiewicz & Rodriguez, 2007). One important aspect of the sTc framework is that it recognizes culturally sensitive information (i.e. Indigenous knowledge)—an aspect that many frameworks do not address (Riggs, 2004). For instance, sTc views teaching and learning as political acts, requiring recognition of the issue of power-holding between teachers/students from dominant groups of society and teachers/students from marginalized groups (Rodriguez & Berryman, 2002). Another example would be the enhanced and contextualized understanding that student's stand to gain from using agency to change their educational experience into an experience more consistent with their cultural values. The centralization of agency and emphasis on transformative practices is the reasoning for the "T" in "sTc" being capitalized.

sTc is composed of four major components: dialogic conversation, authentic activities, metacognition, and reflexivity (Rodriguez, 1998, Rodriguez & Berryman, 2002). Every component of this theoretical framework was used to design the interventions created for the research presented in this dissertation. The dialogic conversation component enables the creation of a respectful space in the learning environment so that students are able to speak freely, with each other and the instructor, without fear of reprimand or belittlement (Rodriguez, 1998). This develops trust between participants of dialogic conversation and is necessary to align with the perspective that knowledge is socially constructed (Rodriguez, 1998). The dialogic conversational space is not free from tension, so respect for other is extremely important to maintain a productive educational environment.

Authentic activities are activities grounded in the previous knowledge possessed by learners (Rodriguez, 1998). Within Indigenous communities this cultural relevancy is necessary in order for learners to scaffold previously held knowledge (i.e. cultural knowledge gained from everyday experiences) with the newly presented concepts being taught in the classroom. Without a meaningful context, learners may see little value in demonstrating knowledge construction (Russell, 2014). Authentic activities can be used in conjunction with dialogic conversational aspects of sTc to create educational experiences that draw from the various perspectives of a group of learners (Rodriguez, 1998). So, a truly authentic activity for one set of learners can be used as an opportunity to learn more about their perspective by a heterogeneous group of learners from various cultural backgrounds within the same educational setting.

The metacognition component refers to the understanding a learner gains from thinking critically about how one's own thinking is being influenced by the educational environment (Rodriguez, 1998). Sometimes this entails student learners questioning why certain knowledge is being taught (Rodriguez, 1998). This also includes omitted information that may be part of an underrepresented student's cultural knowledge but that is not necessarily part of the instructor's previously held knowledge. These omissions can become explicit aspects of the learner's educational context through the use of metacognitive practices. In addition, the metacognitive component of sTc develops an understanding on behalf of the learner for why they are learning certain types of knowledge (Rodriguez, 1998).

Finally, reflexivity describes the way that students put their particular educational experience into a much broader perspective (Rodriguez, 1998). This enables students to

understand why certain information is deemed necessary for their education while other topics are inaccessible in the normal course of education. It is in this reflection that historical, political, and institutional contexts are realized and opportunities for students to transform their educational experience are created (Rodriguez, 1998; Rodriguez, 2008). These four components of sTc (Rodriguez, 1998; Rodriguez & Berryman, 2002) are collectively used to create agency for participants in educational activities. Agency refers to the conscious role that we choose to play in spreading beneficial change for everyone, but especially for disadvantaged individuals and groups of people (Rodriguez, 1998; Rodriguez & Berryman, 2002).

TribCrit describes a theoretical framework where historical contexts of power, especially between Indigenous groups and non-Indigenous groups, and hegemonic control are recognized and actively discussed throughout pedagogical practices (Brayboy, 2005; Zywicki, 2013). Indigenous communities have experienced colonialism and its negative after-effects within the last few hundred years as they have survived genocide, endured forced removal from their homelands/territories, and continue to protest the denial of rights to practice their Traditional cultures freely and without consequence (Minge, 1991; Smith 1999, Zywicki, 2013). Acknowledging this historical context of Indigenous peoples in the United States is necessary to provide Indigenous students an equitable learning environment that can also provide them the agency to transform their communities through the use of Western scientific geologic concepts (Cajete, 2000).

The TribCrit framework is a necessary addition to the research presented in this dissertation because it specifically addresses "Tenet 3: American Indians' liminality as both legal/political and racialized beings" (Brayboy, 2005), which is a vital perspective when working with complexly situated sovereign nations. The full scope of TribCrit (Brayboy, 2005) addresses nine tenets:

1. Colonization is endemic to society.
2. U.S. policies toward Indigenous peoples are rooted in imperialism, White supremacy, and a desire for material gain.
3. Indigenous peoples occupy a liminal space that accounts for both the political and racialized natures of our identities.
4. Indigenous peoples have a desire to obtain and forge tribal sovereignty, tribal autonomy, self-determination, and self-identification.

5. The concepts of culture, knowledge, and power take on new meaning when examined through an Indigenous lens.
6. Governmental policies and educational policies toward Indigenous peoples are intimately linked around the problematic goal of assimilation.
7. Tribal philosophies, beliefs, customs, traditions, and visions for the future are central to understand the lived realities of Indigenous peoples.
8. Stories are not separate from theory; they make up theory and are, therefore, real and legitimate sources of data and ways of being.
9. Theory and practice are connected in deep and explicit ways such that scholars must work towards social change.

All of these tenets are relevant when working with Indigenous communities, especially when working in the capacity of an academic researcher. As Brayboy (2005) notes, these tenets serve Indigenous academic scholars by enabling a way to centralize Indigenous perspectives and providing opportunities for us to maintain our Indigenous identities within non-Indigenous spaces. Furthermore, Brayboy(2005) Tenet 9 expands the discussion in a way similar to sTc by noting that these tenets remain powerless when they are not tied to direct, transformative application of the principles outlined.

Dissertation Overview

The outline of my dissertation also serves as a map of the development of my academic researcher identity. As I finished the detrital zircon geochronological work as part of the M.S. program at Purdue University, I knew that I wanted to share this important Western scientific information with my home community, Acoma Pueblo. However, I also realized that I would need to restructure the information I wanted to convey in order to highlight meaningful relationships the Acoma community already have with their local environment. This theoretical approach resulted in my first publication in *GSA Today* (Reano & Ridgway, 2015) and has been read by many geoscientists across the world. During this early part of my PhD program I decided to seek external research funding from the Geological Society of America (GSA) in order to implement the theoretical approach detailed in that first publication. The resulting work is Chapter 2 of my dissertation.

Chapter 2 is a qualitative analysis of the major connections that Acoma Pueblo community members made between their culture and the Western geoscientific knowledge presented to them in an experiential, hands-on sharing/learning program, the Acoma Pueblo Pilot Project. This was a powerful experience for me because I led the program alone. This allowed me the flexibility I needed to ensure that the various community perspectives were respected in ways that Western science does not always treat as a priority. For instance, rather than lectures about the Western scientific information presented, we had discussions in which interruptions were consistent, necessary, and valued. This formative feedback provided the opportunity to contextualize the information I wanted to share in a way that answered various questions the community members attending the sharing/learning program wanted answered. The results of this pilot project helped contextualize the information I had been researching about Indigenous Knowledge, Traditional Ecological Knowledge, and Indigenous research frameworks in the most relevant way because it was all related to my home community, Acoma Pueblo. Moving forward, in my academic career, I feel a desire to share the power of Indigenous research frameworks with other Indigenous communities, especially within a geologic context.

Chapter 3 of my dissertation came forward as a result of my involvement with the American Indian Science and Engineering Society (AISES). Through a program, AISES Lighting the Pathway to Future Faculty Careers, I met my mentor and collaborator, Jessica Black. Together with my main advisor at the time, Jon Harbor, we formalized a plan for me to prepare a grant proposal that we would jointly submit to the National Science Foundation (NSF). I wrote the bulk of this full NSF proposal ("GeoConnections", Award Number 1712378) and competed with faculty from around the country successfully. The resulting work is highlighted in the second chapter of my dissertation.

GeoConnections is focused on creating culturally-relevant, place-based geoscience educational modules using Indigenous research frameworks such as Tribal Critical Race Theory (TribCrit) (Brayboy, 2005). Additionally, I chose to couple the Indigenous research framework values with those of socioTransformative constructivism (sTc), a framework developed to enact transformative educational experiences for multicultural learners (Rodriguez, 1998). This choice was intentional because while sTc provides an educational forum in which multicultural education is valued, sTc does not intentionally address the specific values that Indigenous communities uphold as inherent to Indigenous epistemology and ontologies which can be perceived as

conflicting with dominant epistemologies. It is important for me, as an Indigenous person, that these underrepresented "ways of being" are brought to the forefront of educational pedagogies, especially those focused on multicultural education. In other words, sTc does provide a respectful space for diverse learners to come together and communicate, but TribCrit provides the specific context of Indigenous learners within that multicultural space inhabited by diverse learners.

GeoConnections was implemented at a private university located within the Yakama Nation community. Dr. Jessica Black is an assistant professor and director of a center focused on Indigenous health, culture, and the environment. Dr. Black and I developed the geoscience education modules (GEMs) together and implemented them together in the Fall semester of 2017 in an introductory environmental science class. I was unable to spend the entire semester co-teaching the class with Dr. Black, but I was able to visit every couple of weeks throughout the semester as we implemented the GEMs and conducted data collection.

The first GEM is focused on carbon sequestration in basalts, a relatively new method of mitigating climate change. The second module emphasized the importance of the Yakima River to the Yakama Nation and surrounding communities. We especially focused on the cultural significance of salmon and lamprey and their relationships to the Yakima River. The third module was related to communication skills needed by scientists and how local, state, and federal policies are impacted by the science community. The conception of this policy and communication module is founded on research from the American Geosciences Institute (Houlton, 2015) detailing the lack of non-technical skills in recently graduated geoscientists.

Our analysis of the GEMs began with a mixed-methods sequential transformative design, led by the use of Indigenous research frameworks. However, with only 15 participants, the quantitative results are not statistically significant. The qualitative analysis of semi-structured interviews of the participants detail critical incidents throughout the implementation of the modules that encourage holistic thinking and the consideration of Indigenous perspectives in relation to the geoscience conceptual knowledge that is being gained. Additionally, many of the participants described how geology and environmental science had distinct connections to the local agriculture industry. Participants also made connections between the agriculture industry and the food products produced, the pesticides used during the production of food products, and the resulting impacts to drinking water.

As GeoConnections completed its first cycle of GEM development and implementation, I began working with undergraduate students to enter the data from the GEMs and create presentations for national conferences such as the Geological Society of America and the American Geophysical Union where undergraduates involved with the project and I have presented preliminary results from the Acoma Pilot Project and GeoConnections. As I was supervising these students, I recognized that these undergraduates deserved the same respect we were describing was needed for undergraduates in the classroom. This was a pivotal time for my intellectual development as I realized that Indigenous research frameworks, due to their holistic nature, could potentially be used for activities beyond research.

Chapter 4 of my dissertation is an autoethnography designed to highlight how my experiences in academia have been influenced by my use of Indigenous research frameworks. As I began designing and implementing the GeoConnections project, I began to see how Indigenous research frameworks could be expanded to mentor students. For the past several years, I have been a mentor for underrepresented students at both the undergraduate and graduate level through the Alliance for Graduate Education through the Professoriate (AGEP) program at Purdue University. More recently, I have been a mentor to Indigenous undergraduates as part of another NSF-funded project, i-NATURE: Indigenous integration of aquatic sciences and traditional-ecological-knowledge for undergraduate culturally responsive education. It was immediately apparent to me that the values enmeshed within the Indigenous research frameworks (e.g. respect, relationality) would work equally well for Indigenous and non-Indigenous students. By putting the Indigenous research frameworks into practice, I saw great benefits in the classes for which I was the teaching assistant. Students communicated with each other more regularly and began to problem-solve as a group, students were making more connections between the technical information we were using and how it would benefit them in their various career aspirations, and also the students began to develop an intergenerational understanding that they were mentors to younger students in the same way that they had their own mentors. It is my perspective that many of these positive outcomes were a result of the respectful communication practices inherent to Indigenous research frameworks.

Conclusion

I have shared the results of my dissertation at many conferences including the Geological Society of America, the American Geophysical Union, the American Indian Science and Engineering Society, the Society for the Advancement of Chicanos/Hispanics and Native Americans in the Sciences, the American Educational Research Association, Earth Educator's Rendezvous, and the Geoscience Alliance (Reano, 2016a; Reano, 2016b; Reano, 2017; Reano, 2018a; Reano, 2018b; Reano 2019a, Reano 2019b). In addition, I have been invited to give presentations about my work at Indiana University and Brown University. Most of these presentations have ended with few questions during the formal period reserved for questions. However, I am often approached by Indigenous and other underrepresented people afterwards to talk in a more informal settings about the topics I presented. This is how I know that the work I am doing is valuable for many others besides myself. It is especially satisfying to see Indigenous scholars begin to wield Indigenous research frameworks in ways that empower their communities and themselves.

As I continue on my academic pathway, I see institutions of higher education becoming inclusive spaces for students from many backgrounds. Currently, there are many challenges and barriers that have kept us from realizing this goal already. Many institutions have diversity and inclusion advisory committees that have been tasked with advancing the goal of equitable education for all students. These initiatives will require an increased understanding of multicultural education, equitable pedagogical practices, and an increased awareness of intercultural communication. All of these objectives can be addressed using Indigenous research frameworks. It is my hope that this dissertation will not be manipulated in ways that harm Indigenous communities through disrespectful behaviors such as cultural appropriation and discrimination. However dangerous the potentialities are for sharing the values of Indigenous research frameworks, I feel that future generations of Indigenous scholars as well as those non-Indigenous scholars who have an authentic desire to become true allies need the armor of Indigenous research frameworks. This is what I have to offer.

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EMPOWERING TRADITIONAL KNOWLEDGE USING INDIGENOUS RESEARCH FRAMEWORKS AT ACOMA PUEBLO, NM

Introduction

Acoma Pueblo is a place of rich cultural diversity, situated among many different Indigenous cultures, and is visually striking because of outcrops of sedimentary rocks dating back millions of years (Figures 1 & 2). As one of the oldest continually inhabited villages in the United States, Acoma Pueblo community members have valuable insight into how Indigenous groups of people value and respect the local geology of their homelands. Every year, the Acoma Pueblo community hosts Earth Day events that are meant to highlight the many ways that Acoma is connected to the earth as well as how these connections impact the overall health and well-being of the Acoma Pueblo community.

As a member of the Acoma community, I saw an opportunity to use my training as a geologist to participate in these events by creating place-based geology education materials that could be used by the community's schools and educational enrichment programs. The day-long geoscience educational module I developed, "Sharing and Learning: The Natural Environments of Acoma Pueblo", provided an opportunity to explore the various connections that Acoma Pueblo community members make between their cultural values and the geologic concepts that were presented during the module. The purpose of such an exploration is to make explicit the cultural understandings of the geologic environment that bring meaning to the Western scientific knowledge, for both future Acoma Pueblo community members and other Indigenous scholars. This is different from the isolated geologic understandings that Acoma community members would receive if the geologic information was shared within a primarily Western scientific context such as is common in a public school setting. The Sharing/Learning Program was held in the Acoma Community Center, a social meeting place for community members across the Acoma Reservation. In addition, this Sharing/Learning Program was implemented as informally as possible with particular emphasis placed on the expert cultural knowledge that Acoma Pueblo community members already held before attending the Sharing/Learning Program. The privileging of Indigenous knowledge allowed the participants to make meaning of the presented geoscience concepts through a cultural lens that resulted in the recognition of direct relationships

between Acoma Pueblo cultural values and geoscientific concepts. The term I will use to describe these connections between culture and geology is “geoconnections”.

Figure 1. Acoma Pueblo is located on top of a mesa within the southwestern United States.

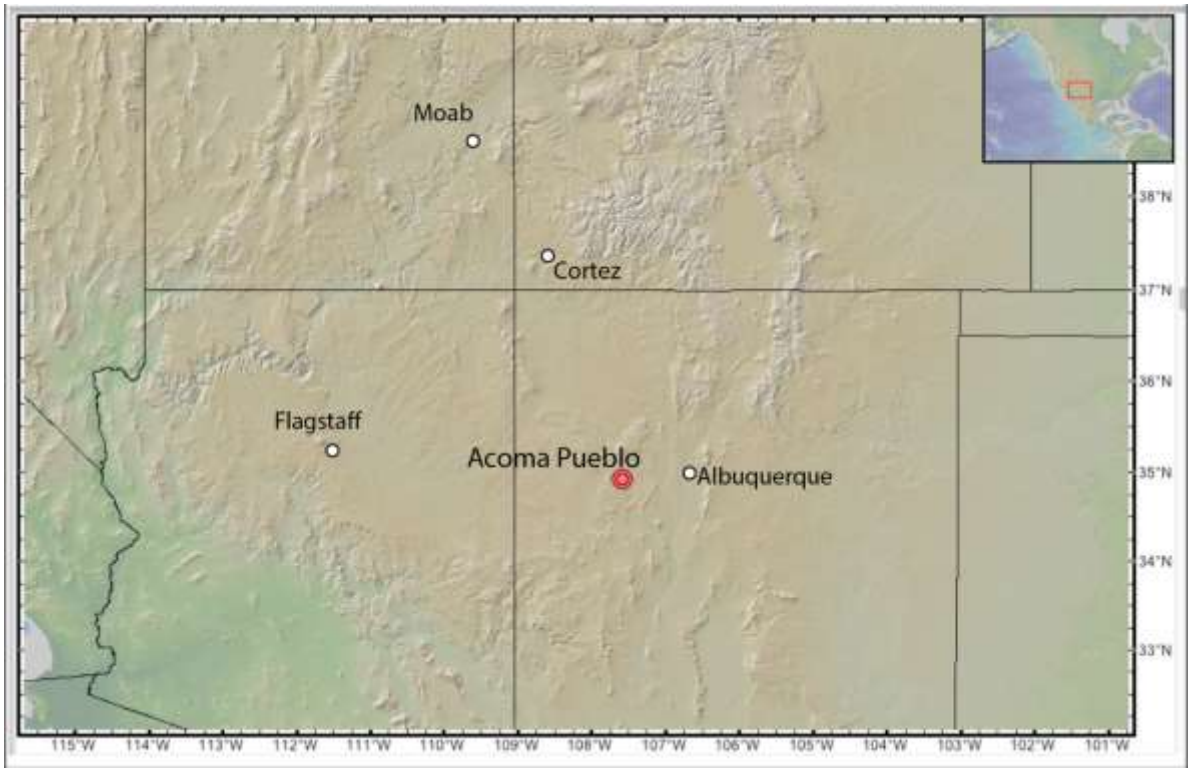

Figure 2. Acoma Pueblo, NM (red dot) is located about sixty miles west of Albuquerque, NM. Map from: http://www.geomapapp.org

Theoretical Framework

The guiding perspective for this study is a combination of the socioTransformative constructivism, sTc, framework (Rodriguez, 1998) and Tribal Critical Race Theory, TribCrit (Brayboy, 2005). The sTc framework proposes that knowledge "is socially constructed, mediated by cultural, historical, and institutional contexts", and can often result in meaningful dialogues among participants concerning their local communities (Rodriguez, 1998; Rodriguez & Berryman, 2002; Zozakiewicz & Rodriguez, 2007). sTc views teaching and learning as political acts, requiring recognition of the issue of power-holding between majority teachers/students and minority teachers/students (Rodriguez & Berryman, 2002). This is especially important within Indigenous communities where Western hierarchical social orders may not align with traditional power structures of specific Indigenous communities.

sTc relies upon four main components to create transformational educational environments: dialogic conversation, authentic activities, metacognition, and reflexivity (Rodriguez, 1998, Rodriguez & Berryman, 2002). Every component of this theoretical framework played an important role in the development of the place-based educational activities that were created to enhance connections between culture and geology for Acoma community members. According to Rodriguez (1998) the dialogic conversation component is a way of creating a respectful, safe space in the sharing/learning environment so that participants are able to speak freely and share their culturally-based knowledge and beliefs with each other, and without fear of reprimand or belittlement. However, it should be noted that this does not mean that the conversations are without tension or disagreement. The dialogic conversation component is also necessary to align with sTc's stance on the social construction of knowledge (Rodriguez, 1998). Authentic activities must be culturally relevant in order for learners to be able to scaffold previously held knowledge (i.e. Indigenous knowledge) with the newly presented concepts being taught in the classroom. Without a meaningful context, some learners have been shown to be unable to demonstrate knowledge construction (Russell, 2014).

The metacognition component requires student learners to question why certain knowledge is being taught (Rodriguez, 1998). This also includes omitted information that may be part of an underrepresented student's cultural knowledge but that is not necessarily part of the instructor's previously held knowledge. Finally, reflexivity describes the way that students put their particular educational experience into a much broader perspective (Rodriguez, 1998). This enables students

to understand why certain information is deemed necessary for their education while other topics are inaccessible in the normal course of education. It is within these critical thinking activities that historical, political, and institutional contexts are realized and opportunities for students to transform their educational experience are created (Rodriguez, 1998; Rodriguez, 2008). These four components of sTc (Rodriguez & Berryman, 2002) are collectively used to create agency for participants in educational activities. Agency refers to the conscious role that we choose to play in spreading beneficial change for everyone, but especially for disadvantaged individuals and groups of people (Rodriguez & Berryman, 2002). While sTc can be used in many contexts, specific Indigenous research frameworks (e.g. Tribal Critical Race Theory) have been developed to ensure that the needs of Indigenous communities are not neglected during the implementation of research activities. I have therefore combined the use of sTc and Tribal Critical Race Theory to design and implement the Sharing/Learning Program.

Tribal Critical Race Theory (TribCrit) describes a theoretical framework where historical contexts of power, especially between Indigenous and non-Indigenous peoples, and hegemonic control are recognized and actively discussed throughout pedagogical practices (Brayboy, 2005; Zywicki, 2013). Indigenous communities continue to experience colonization and its negative effects within the last few hundred years as they have survived genocide, endured forced removal from their homelands/territories, and continue to protest the denial of rights to practice their Traditional cultures freely and without consequence (Minge, 1991; Smith 1999). Acknowledging this historical context of Indigenous people in the United States is necessary to provide Indigenous students with an equitable learning environment that can also provide them the agency to transform their communities through the use of Western scientific (e.g. geologic) concepts (Brayboy, 2005; Atwater et al., 2014; Masta, 2018). TribCrit is a necessary addition to our project framework because it specifically addresses "American Indians' liminality as both legal/political and racialized beings" (Brayboy, 2005), which is a vital perspective when working with complexly situated sovereign nations. The full scope of TribCrit addresses nine tenets (Brayboy, 2005), but the most critical tenets of TribCrit that are relevant for this project are: colonization is endemic to society; the meaning of the concepts of culture, knowledge, and power can be uniquely understood through an Indigenous lens; and Tribal philosophies, beliefs, customs, traditions, and visions for the future are necessary to understand the lived realities of Indigenous peoples (Brayboy, 2005).

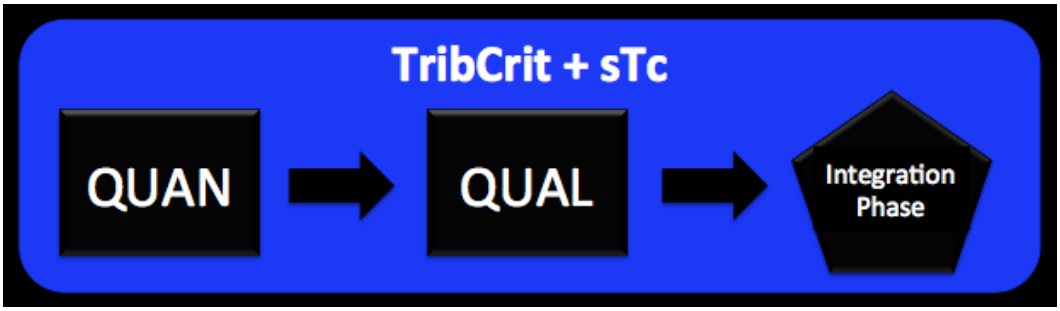

Figure 3. Sequential transformative research design showing the sequential collection of datasets followed by an integration phase. Both datasets were treated as equally important during implementation of the study, however only the qualitative data is analyzed in this article.

The Indigenous Research Framework for this project thus combines TribCrit with sTc (Figure 3) so that the specific historical contexts of Acoma Pueblo community members were actively integrated into the Sharing/Learning Program, while at the same time allowing the participants to impact their experience within the Sharing/Learning Program and transform that experience into something the learners feel will benefit themselves and the Acoma Pueblo community. The research question of this project is to explore Acoma community members' connections to geoscience concepts after participating in a Sharing/Learning Program designed to teach earth science concepts developed from an Indigenous perspective.

Methodology

Participants

I grew up immersed within the Acoma Pueblo culture and maintain connections to my family and community there. My perspective, as an Acoma Pueblo community member and academic researcher, is uniquely situated to draw attention to geoconnections while also maintaining respect for the role of Acoma Pueblo's governing bodies in determining what is appropriate to publicize and share with outsiders to our community. I offered control over what was appropriate to share in the Sharing/Learning Program by meeting with the Acoma Pueblo Tribal council before the field research that informed the Western science information within the Sharing/Learning Program, before the implementation of the Sharing/Learning Program, and also as I began to prepare the written text for this chapter to report the results of the Sharing/Learning Program.

15 participants came to events for the Sharing/Learning Program. These Acoma Pueblo community members were 7 children (under the age of 18) and 8 adults. As discussed in the introduction to this dissertation, some of the participants maintain a role as an Elder in the Acoma Pueblo community. Other Indigenous scholars have maintained that Indigenous knowledge is held in community and that Elders and youth each provide useful aspects of the Indigenous knowledge system (Smith, 1999). Italics will be used to differentiate quotes of these Indigenous perspectives from the Western scientific product that this dissertation represents. In order to avoid the automatic over-privileging of Indigenous Knowledge shared by Acoma Elders, the attributions of quotes in the results section are labeled only as "Acoma Pueblo community member". This is one way of practicing Indigenous data sovereignty on behalf of the Acoma community. Indigenous data sovereignty refers to "the right of Native nations to govern the collection, ownership, and application of its own data (not limited by geographic jurisdiction or digital form)" (Raine et al, 2017; David-Chavez & Gavin, 2018). The rich information presented in this chapter will only fully be wielded by other members of the Acoma Pueblo community. The purpose of this pilot project and the future publication of this chapter will serve to illustrate to future Indigenous scholars from Acoma Pueblo and other Indigenous communities one example of how Western science can be called to serve the interests of Indigenous communities.

Methods & Research Design

The Sharing/Learning Program was implemented as a day-long geoscience educational experience for Acoma Pueblo community members. The focus of this Sharing/Learning Program was to connect depositional environments of sedimentary rocks with everyday uses of those earth materials by Acoma Pueblo community members (Reano & Ridgway, 2015). The researchers for this project refer to these connections between culture and geology as "geoconnections", but other researchers may have multiple terms for these connections depending on the specific relationships involved (Semken, 1997; Smith, 1999; Garcia, 2018; Gibson & Puniwai, 2006; Cajete, 2008; Chinn, 2008; David-Chavez & Gavin, 2018). The primary research question concerns "What connections do Acoma Pueblo community members make between their cultures and Western Geoscience after participating in a day-long geoscience Sharing/Learning Program to enhance understanding of depositional environments of the local geology at Acoma Pueblo?"

Participants completed a "sense of place" assessment (modified from Semken & Freeman, 2008; Appendix A) at the start of the Sharing/Learning Program and then received typical geological tools used in an introductory geology course (a hand lens and a grain size card) that participants used to observe and describe the mostly sedimentary rocks (Dakota Sandstone) that make up the building structure that the program was held in. Participants were also encouraged to describe geoconnections during a "gallery walk" in which posters of various depositional environments were hung on the walls and participants used post-it notes to describe their own personal geoconnections to the various representations of geology. At the end of the Sharing/Learning Program, participants engaged in a post-program sense of place survey, identical to the pre-program sense of place survey, and a group discussion about what the participants felt about the Sharing/Learning Program. The discussion allowed participants to describe the various aspects of the program that they enjoyed most as well as to communicate which geoconnections were most interesting to them given their exposure to new Western geoscientific knowledge. This conversation between participants was facilitated using the principles of dialogic conversation, as described in the theoretical framework section of this chapter (Rodriguez, 1998).

A sequential transformative design (Figure 3) was initially used to plan for a mixed methods (MM) assessment of the impacts of place-based educational modules on students' connections to geoscience concepts and careers. A sequential transformative design consists of the collection of quantitative and qualitative data with a strong theoretical perspective that guides the study's research questions (Creswell et al., 2003). This design calls for the integration of the qualitative and quantitative data during the interpretation phase of the study after both datasets have been collected. This type of mixed method study treats the qualitative and quantitative data equally so that both sets of data are of high quality and the sequential order of data collection enhances the study's findings (Creswell et al., 2003). This chapter will focus primarily on the qualitative data that was collected at the end of the Sharing/Learning Program.

The assessment for the project began with quantitative data collection using a modified, validated survey instrument (Appendix A) before implementation of the Sharing/Learning Program and the exact same instrument was used after implementation of the Sharing/Learning Program to ask the same questions designed to assess sense of place, specifically Acoma Pueblo. Eleven participants responded to the sense of place survey instrument before and after implementation of the Sharing/Learning Program. The sense of place survey instrument was

modeled after a previous iteration of the instrument that was designed to detect changes in students' sense of place (Young, 1999; Williams & Vaske, 2003; Semken & Freeman, 2008; Ward et al., 2014). In the context of our project, sense of place refers to the emotional, spiritual, and other affective responses to a particular geographic location experienced by people (Semken, 2005; Semken & Freeman, 2008; Semken et al., 2009; Garcia, 2018).

The place attachment portion of the sense of place survey (Appendix A) asked a total of 12 questions and used a 5-point Likert scale to determine the relationships that the participants have regarding Acoma as a place both before and after the geology-focused Sharing/Learning Program. The sense of place survey was typed out with a 1 on the 5-point Likert scale representing "strongly agree" and a 5 on the scale representing "strongly disagree". During analysis, we transposed the scores so that higher values on the 5-point Likert scale corresponded to increased place attachment. Question 12, "The things I do at Acoma I would enjoy doing just as much at a similar place" (Appendix A) was scored so that disagreement with the statement corresponded to higher place attachment. In our attempt to reproduce studies that have used this sense of place survey before (Young, 1999; Williams & Vaske, 2003; Semken & Freeman, 2008; Ward et al., 2014) we summed the total scores to get a summative place attachment score. Semken & Freeman (2008) established summative scores of 36-60 as indicative of place attachment and summative scores <36 as indicative of place aversion.

For the qualitative component, a semi-structured group interview was conducted with all of the participants who attended the Sharing/Learning Program. This group interview included only 13 participants as two of the participants left before the end of the Sharing/Learning Program. An audio recording of this interview was transcribed and analyzed qualitatively to identify critical incidents which may have impacted participants' perceptions and conceptions of geology, geoscience concepts, geoscience careers, and the relevance of geology to their daily lives

Quantitative Results

Semken & Freeman (2008) discuss several reasons why a quantitative instrument such as the sense of place survey may not always capture the nuanced "sense of place" of individuals and that caution should be exercised before using the sense of place survey as "an absolute measure of the meanings a place holds for a respondent" (Semken & Freeman, 2008). Instead, Semken &

Freeman (2008) focus on the change in sense of place from before to after the implementation of an educational intervention.

After completion of the Sharing/Learning Program, we performed normality tests on the place attachment results of the sense of place survey. The datasets were normally distributed and so we then used a paired sample *t*-test analysis to determine whether there was a statistical difference in the survey results from before and after implementation of the Sharing/Learning Program similar to previous uses of the sense of place survey (Semken & Freeman, 2008).

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PAQpreSLP	49.0000	11	5.89915	1.77866
	PAQpostSLP	51.4545	11	5.95590	1.79577

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	PAQpreSLP & PAQpostSLP	11	.697	.017

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	PAQpreSLP - PAQpostSLP	-2.45455	4.61224	1.39064	-5.55309	.64400	-1.765	10	.108

Figure 4. Paired sample *t*-test results from quantitative analysis of the place attachment portion of the Sharing/Learning Program sense of place survey.

The paired sample *t*-test (Figure 4) indicated that the quantitative dataset had an insufficient number of participants (n=11) to easily see changes to place attachment that the participants have towards Acoma (p=.108). The mean score from the place attachment survey before implementation of the Sharing/Learning Program is 49 (Figure 4). This mean score value increased to 51 after implementation of the Sharing/Learning Program (Figure 4). Both values indicate place attachment (values 36-60) as opposed to place aversion (values < 36).

One potential reason for this minor difference in the mean score values from before and after implementation of the Sharing/Learning Program is that the sense of place survey does not account for individuals that already have a strong "sense of place" or "place attachment". Since, the Acoma Pueblo community members expressed in the closing group discussion that their

identities are directly tied to the local landscape, it is unlikely that a single day spent discussing geoscientific concepts would significantly change their perception of Acoma Pueblo as a place. This instrument may be better suited for longer-term educational interventions such as the context used in Semken & Freeman (2008).

Qualitative Results and Findings

While a major part of this project is to privilege Indigenous perspectives, it was also important to the researchers that Western scientific perspectives were equally represented, and so not everyone who contributed to this project identifies as a member of an Indigenous community. We developed an iterative coding scheme where individual coders (4 total) progressively identified and then subsequently modified the codes used to analyze the transcript. All four coders self-identified as geoscientists and have had basic training in Western geoscience to at least the undergraduate level. The purpose of including these non-Indigenous geoscientists in the code development was to ensure that the Western geoscientific concepts within the analysis were recognizable and agreed upon by members-at-large from the academic geoscience community. In our analysis we offer a unique set of perspectives that led us to distinguish 6 main emergent themes (Traditional Knowledge, Western Geoscience, Education, Stories, Natural Resources, and Geoconnections) that persisted throughout the focus group interview.

The final analysis presented in this paper is the product of the primary researcher's (Darryl Reano) singular analysis of the final interview using the set of codes developed and agreed upon in conjunction with the other geoscientist researchers. Our analysis identified 6 major emergent themes in the transcript: Traditional Knowledge (TK), Western Geoscience (WG), Education, Stories (including personal experiences), Natural Resources, and Geoconnections (between TK and WG). Each of these major emergent themes had several sub themes that are connected through the major emergent theme. The following paragraphs will describe in more detail the criteria used to designate passages within the transcript as part of a particular emergent theme as well as provide examples of each theme.

The **Traditional Knowledge (TK)** theme was used to indicate instances where participants described culturally invested processes, materials, and or ideas relating to the physical earth, spiritual beliefs of the Acoma Pueblo traditional religion, as well as contemporary sources of practical, traditional knowledge relevant to current household practices (such as cooking, farming,

and ranch duties). Within the TK theme we had one major sub theme we designated as "responsibility of future generations". Indigenous spaces often involve elders from the community passing on traditional knowledge to younger generations which can include both explicit and implied sets of responsibilities. We also included passages that contained behaviors or motivations linked to striving for advancement (i.e. being more knowledgeable, communicating traditional practices, as well as purposeful teaching, etc.) in any aspect.

Examples of passages from the transcript that fit into this theme include (brackets have been added by the researcher for clarity):

> *"Those cottonwood trees, we used to make bubblegum out of those things."*
>
> ***-Acoma Pueblo community member***

> *"Also learning from our elders too about those stories. I never knew about the whole thing about the runners, how they put that [earth materials] on their legs. I never knew that."*
>
> ***-Acoma Pueblo community member***

> *"Well, for people who have built their houses for centuries, thousands of years, that's an important idea. How to find that kind of stuff [stones] to build. Even though they did that a long time ago and knew about that, somebody who's building the house right now might get the wrong kind of stone and cause some of their house to deteriorate just because of the erosion."*
>
> ***-Acoma Pueblo community member***

In these quotes, Acoma Pueblo community members are identifying earth materials that have cultural value within the community. Cottonwood trees are used for a treat, earth materials impart culturally-value attributes (i.e. swifter running), and also provide a means for survival (e.g. the building of homes). The Acoma Pueblo community member speaking about building homes recognize that this information is valuable by providing an example of what could happen if this

Traditional Knowledge is not used: the home that is built from the wrong stones will deteriorate. These three quotes are exemplary of authentically situated examples of how the Acoma Pueblo community relies on earth materials because they are referring to earth materials found locally on the Acoma Pueblo reservation.

The **Western Geoscience (WG)** theme applied strictly to Western scientific topics that were referenced, either from the geoscience education module or from previously held knowledge of the participants. The use of basic, academic Western geoscience terminology and jargon were automatically included in this theme. The other major subtheme we included with WG was "time". The passage of time was used by participants to describe geologic changes in the local environment within a human timescale.

Examples of passages from the transcript that fit into this theme include (brackets added by the researcher for clarity):

> *"But it's really interesting to see how those changes have evolved. How those changes have been made and we look at a rock and we really don't see anything except a rock. But then this helps to learn the different layers and kind of visualize or imagine how many millions of years it took [to form that rock]."*
>
> ***-Acoma Pueblo community member***

> *"The story of that it talks about...why lava has all those bubbles and vesicles."*
>
> ***-Acoma Pueblo community member***

> *"It's just about the geology but I think that geology is where sand comes from. The geology is where our air come from. The geology is where everything else came from. All the chemical makeup of all the rocks that we have on this earth created our waters, created our air."*
>
> ***-Acoma Pueblo community member***

> *"There's things we do all the time, there's things we see all the time…erosion and changes and systems and like I said, the morphology of all the rocks around there."*
>
> ***-Acoma Pueblo community member***

One of the community members is referring to how some people simply "see a rock" but now they also see "how many millions of years it took" to form that rock. This is an example of metacognitive thinking that has engaged the community member to think about how what they are seeing, "different layers", could be explained from a Western scientific perspective. This community member has made a direct connection between everyday rocks and the geoscientific processes that created that rock.

The second quote in this theme represents a direct connection between a culturally significant story that describes how geologic features were created. Since this dissertation will be viewed by many outsiders to the Acoma Pueblo community members, I will not explain what story was shared with the participants. But I will go so far as to say that the story was changed as a result of the Sharing/Learning Program because the words "vesicles" and "lava" were used to describe the geologic features within the story. This is an example of how the geoscientific information presented in the Sharing/Learning program was used to enhance the Traditional Knowledge shared within the story. As a result, listeners of the story learned both the culturally significant story, but their geoscientific knowledge was reinforced through the use of geoscience jargon that was also presented during the Sharing/Learning Program.

The **Education** theme was used to indicate when participants advocated for increased learning opportunities for teaching and learning. This theme was also used to indicate when participants expressed satisfaction that the community is benefiting from the Sharing and Learning Program. In addition, we had three subthemes that had a marked, direct relationship to the Sharing/Learning Program: "interest", "gratitude", and "curiosity". We used the interest subtheme to describe instances where participants expressed personal interest in learning more about Traditional Knowledge and/or a Western scientific concept. Interest also included references to specific aspects of the program that the participants explicitly said they enjoyed. The gratitude subtheme was used to designate passages where participants expressed an appreciation for receiving knowledge (TK and WG). Curiosity designated passages where participants asked a

question about the environment or if the participant expressed an interest in a concept related to the environment.

Examples of passages from the transcript that fit into this theme include:

> *"I really wish they would do that with the water, with hydrology. Do that a lot more so that we get to understand who we are as Acomas and have more pride in what our land is all about."*
>
> ***-Acoma Pueblo community member***

> *"How can we raise better crops, more crops. How can we raise better animals, more healthy animals? How can we sustain ourselves here?"*
>
> ***-Acoma Pueblo community member***

> *"In terms of the kids that are here, sometimes that would've been a good thing to have brought all different kind of other samples. You brought a few in, but maybe just grab a whole bunch and let them decide, like a little test with just sedimentary or just igneous."*
>
> ***-Acoma Pueblo community member***

> *"All this teaching is very helpful to get the idea of how those changes happened and how that came about. So, thank you very much for enlightening us."*
>
> ***-Acoma Pueblo community member***

In the first quote, the Acoma Pueblo community member is remarking on how the land is only one aspect of a holistic identity that Acoma people hold. Water and "hydrology" are also important to the identity of Acoma people. In addition, the third quote listed is describing how one community member is already thinking ahead to how the Sharing/Learning program could be improved. This community member is practicing their agency by consciously deciding how they

would modify the educational experience to provide a different learning experience for the younger generation.

Another major theme from our analysis indicated intense personal relationships directly with the environment as well as social events that happened in particular localities within the environment. These memories/personal experiences were frequently recounted throughout the entire group interview and were often used as a way to provide context for Traditional Knowledge (e.g. how it is known, why it is used, historical relationships). To showcase such a broad theme, we decided to use a broad term, **Stories**. This is not meant to diminish the importance of the knowledge carried within these remarks. One of the tenets of TribCrit specifically points out that "stories are not separate from theory; they make up theory and are, therefore, real and legitimate sources of data and ways of being" (Brayboy, 2005). Within the stories theme we included these subthemes: family, community, personal experiences, and recreation.

Examples of passages from the transcript that fit into this theme include:

> *"I remember my sister, she was up there already registering people and I guess that year there was prickly pears and everybody was picking off them."*
>
> ***-Acoma Pueblo community member***

> *"My mom used to tell me about how to build a house, even though she never built a house. She watched her father, [Participant name]'s father and other uncles build homes. She would always call those rocks different things."*
>
> ***-Acoma Pueblo community member***

> *"We used to make necklaces out of those seeds come up and maybe that's how that tree grew up on top. The only tree we have. Because as kids we run around with a bunch of those leaves and maybe that's where it created that plant. Now look how big it is. That's the only tree we have on top."*
>
> ***-Acoma Pueblo community member***

> *"But it used to be a big hill and it was a long ways on the North side. We used to slide down that way (laughing). Then try to climb back, get up there, push each other down all the way to the bottom and there were no weeds at all. It was just clean sand dune. We don't wear shoes and we don't get scratched on our legs but now all there are all those weeds."*
>
> ***-Acoma Pueblo community member***

The third and fourth quotes are both examples of reflexive thinking patterns that the Acoma Pueblo community members are exhibiting. The third quote shows how the community member is connecting these stories of playing as a child with seed necklaces to the potential impacts to the environment, such as a tree growing on top of the Acoma Pueblo mesa. They are connecting their experiences to a broader recognition of how their actions could be impacting the environment. The fourth quote describes how environmental changes influence children's recreational activities. The fact that the community member describes "weeds" covering a formerly "clean sand dune" provides evidence that the community member is recognizing specific examples of how the environmental landscape is changing over time. In this case, it is not a result of human influence on the environment, but rather the environmental changes are influencing human behavior.

The **Natural Resources** theme was used to highlight passages that specifically mentioned earth (e.g. rocks) and water resources for the Acoma Pueblo community. This theme included the cultivation of these resources as well as when participants described the uses for these resources.

Examples of passages from the transcript that fit into this theme include (brackets added by the researcher for clarity):

> *"It's about resources. I've always liked and enjoyed natural resources. Then everything we talked about, the land is one important theme to all of us, especially here at Acoma."*
>
> ***-Acoma Pueblo community member***

> *"We have a lot of problems and a lot of concerns with water. Not only that, but other natural resources, as well."*
>
> ***-Acoma Pueblo community member***

> *"Even though we don't build that much with those kinds of materials anymore, the understanding on how we built things [homes] and why we used what we used [earth materials] to build them… is learning about geology, about how the particular properties of any kind of mineral or stone are important to us."*
>
> ***-Acoma Pueblo community member***

The third quote is another example of reflexivity. The community member is thinking about how some Traditional Knowledge is being lost because "we don't build that much with those kinds of materials anymore". However, they also make the connection that Western science is connected to those same ideas of Traditional Knowledge because both knowledge systems are concerned with "the particular properties of any kind of mineral or stone". The community member takes this information and finds relevance in it as well because the properties of different earth materials impacted "how we built things and why we used what we used to build them".

The **Geoconnection** theme was used when participants described connections between Traditional Knowledge and Western Geoscience, with identity as a subtheme. We coded passages as "identity" if participants identified their identity, if they described a connection between their identity and the Sharing/Learning Program, as well as when participants described aspects of the Acoma Pueblo community's identity.

Examples of passages from the transcript that fit into this theme include:

> *"The earth is our mother and what we learn from it. All of this to make one big connection with who we are. Just our identity. As a people, as a society, and the individuals. All of us that sit here as humans make that connection."*
>
> ***-Acoma Pueblo community member***

> *"Why do those sand dunes move? And where have they gone in the climate of our area? Even though that relates to a story of how she grew up, it is science. It is science…The idea though is that they're all kind of - how do they say that word - interconnected."*
>
> ***-Acoma Pueblo community member***

> *"She said, 'Don't ever build a house with that sugar rock.' And I said, 'Sugar rock? I'll just take that off that …' (laughs) She said, 'Yeah, that's sugar rock,' and I said, 'What's the difference?' 'It's that kind of rock that falls apart.' I said, 'Oh, you mean like sandstone?" Of course, maybe mom didn't really understand sandstone, limestone, whatever. It's sugar rock."*
>
> ***-Acoma Pueblo community member***

The third quote is an example of why using Indigenous research frameworks such as TribCrit is so important when communicating with Indigenous people. The community member is expressing how stories can be used to transmit scientifically sound information. This is precisely why one of TribCrit's tenets states that "stories are not separate from theory; they make up theory and are, therefore, real and legitimate sources of data and ways of being" (Brayboy, 2005). In this particular instance, the community member is describing the how geoscientific disciplines (e.g. geologic processes are influenced by climate) are all connected.

Discussion & Implications

Since we used an approach that encouraged individuals to direct the conversation towards topics they wanted to discuss, the geoconnections recognized in this analysis feature direct communication of the values that Acoma Pueblo community members have in relation to geoscience. We have purposefully used "geoscience" rather than "geology" because we wanted to be more inclusive of non-geology disciplines related to the Earth (e.g. biology and chemistry).

The objective of this project was to explore connections that the Sharing/Learning Program participants made between their culture and Western modern science, "geoconnections". The geoconnections that participants made included: building traditional homes from specific

sandstone layers, changes in the physical configuration of geomorphic features (e.g. migration of sand dunes, weathering and erosion of Acoma Mesa), as well as using earth materials to cook food. However, the geoconnections also included connections between their culture (Traditional Knowledge) and other non-geologic disciplines such as the harvesting of prickly pear berries (biology) for natural dyes (chemistry), the harvesting of other traditional foods (sweet potatoes, agronomy), the human impact of wearing seeds as necklaces (cultural behaviors interacting with the environment) on the movement of plants (tree on top of mesa, ecology).

> *"We used to make necklaces out of those seeds come up and maybe that's how that tree grew up on top. The only tree we have. Because as kids we run around with a bunch of those leaves and maybe that's where it created that plant. Now look how big it is. That's the only tree we have on top. That's about 40-, 50-year-old tree there."*
>
> ***-Acoma Pueblo community member***

> *"We used to pick whatever Mother Nature put out there, like…that sweet potato. It's real sweet. That's our candy because those leaves are sweet"*
>
> ***-Acoma Pueblo community member***

> *"We were charging down below because of the prickly pears up there (laughing). Everybody was up there picking."*
>
> ***-Acoma Pueblo community member***

Another topic that our analysis indicated was important is how the participants defined Traditional Knowledge. As trained, Western scientists our conception of Traditional Knowledge is influenced by non-Indigenous ways of knowing. However, an exciting outcome from the closing group discussion with the Sharing/Learning Program participants was that they collectively began to describe in their own words what their conceptions of "Traditional Knowledge" and "Traditional Education" are and how they are different from Western Science. From the Acoma

perspective, Traditional Knowledge has utility. It is not simply knowledge for the sake of having knowledge, but it has a purpose or usefulness for the people living within a particular environment:

> *"Please children, listen and learn a lot of our culture and our land that our ancestors left for us too, to use and live on this world… This is our home. This is our life here. Even though you may say you won't come home, it's too hard living on the Rez, but someday you're going to come home. You're going to live here, back where you belong."*
>
> ***-Acoma Pueblo community member***

> *"A lot of those stories that I've taught, even to my own children maybe I don't know if they remember, kind of put a tie on that on why we need to understand, why we need to know it. And why science is important for us to understand what happened, even though it might be a story."*
>
> ***-Acoma Pueblo community member***

> *"That's what Pueblo people and Indian people have always done. We've always learned it as a group of understanding and never as a math or a geology or uh English. It's all been one whole thing, one whole idea. I think maybe that's ... Darryl's trying to make it into how it used to be. How we used to live."*
>
> ***-Acoma Pueblo community member***

Traditional teaching practices were described as recognizing the interconnectedness of the natural world and its relationships to people, animals, and other lifeforms within the environment. This concept is also described as something that is being forgotten, or less utilized than in previous generations. Teaching and learning environments vary between teachers but several characteristics are described during the group discussion: maintenance of a spiritual connection/resurgence of traditional values/maintaining self as a member of the community,

"Don't ever disconnect yourself from your people, from who you are as Acomas...come back and share some of that."

-Acoma Pueblo community member

"I think Darryl trying to make that connection is trying to go back to how we used to be. Trying to learn and understand how our environment is and how it relates to us."

-Acoma Pueblo community member

"Then we can at least come with some understanding on how we need to live and not take charge of any of it, but to use it to help us to continue to live. There's not very many of us anymore and I know there's a lot of people that need to know this information."

-Acoma Pueblo community member

"Maybe other communities might not see this, but for us, I think it's something we've been doing for centuries and we're not doing that as much anymore. I think maybe students like Darryl and all the other guys that are going to college and universities, I hope they have that same sense of idea that you can learn these things but don't disconnect from where you come from, in terms of how they relate to your lives. And your religion. I think that's a good point."

-Acoma Pueblo community member

"But not knowing those things [Traditional Knowledge] I think is a way that we're losing part of our identity. That even though we don't build that much with those kinds of materials anymore, the understanding on how we built things and why we used what we used to build them is nothing but part of what they're all is learning

> *about geology. About how the particular properties of any kind of mineral or stone are important to us."*
>
> ***-Acoma Pueblo community member***

Western science was described by the participants as being associated with "facts" and textbook knowledge, in a way that is decontextualized or "separate":

> *"We're kind of used to the Western version of learning, so public school systems. It's just textbooks and facts and whatever."*
>
> ***-Acoma Pueblo community member***

> *"Western education - the way that all of you have gone to public school or college or university - always kind of separate. They call 'compartmentalize' stuff."*
>
> ***-Acoma Pueblo community member***

This Sharing/Learning Program is different from many other community outreach programs. Our Sharing/Learning Program was designed using Indigenous research framework components (e.g. Tribal Critical Race Theory) that work effectively to diminish power hierarchies that normally inundate learning environments with stressful emotions such as fear, shame, and embarrassment. Our use of Tribal Critical Race Theory called for the facilitator of the Sharing/Learning Program to explicitly acknowledge that all of the participants had valuable knowledge to offer and share during the Sharing/Learning Program. The participants thus took control of the final group discussion to serve their cultural values of showing thanks for the activities as well as the information shared by the elders throughout the day. During the hands-on activities where participants were able to work in small groups and have their own discussions, the Acoma community behavioral norms helped empower Sharing/Learning Program participants of all ages to share information and ideas about the earth materials we were observing as well as their past experiences within the Acoma community. Finally, during the final interview, participants were not heavily questioned about what particular aspects of the Sharing/Learning Program were most prescient for them, but rather participants were allowed to frame their experience in their

own words, allowing for context-driven, sociohistorical descriptions that embody the complex relationship Acoma Pueblo community members have with their environment. The group discussion was dominated by elders from the community, which is a normal pattern of behavior in group settings at Acoma Pueblo.

The rich cultural understandings of Acoma Pueblo as a place for nurturing direct relationships with the local geology are explicit and direct. Many of the participants recognized a need for a balance between cultural revitalization and promulgation of Traditional Knowledge while at the same time incorporating Western scientific knowledge into their framework for dealing with outsiders to the Acoma Pueblo community.

> *"A lot of these things, these stories, these ideas, these concepts are not in any book anywhere. They're all in the people that grew up listening to these things. Unfortunately, we're not at a point where we're really that comfortable as a tribe to actually write these things down. Or even to interview people…Once we can do that, then we can at least come with some understanding on how we need to live and not take charge of any of it, but to use it to help us to continue to live. There's not very many of us anymore and I know there's a lot of people that need to know this information."*
>
> ***-Acoma Pueblo community member***

From the community's perspective, they have control over the enculturation of Acoma Pueblo cultural values and practices but they do not yet have complete access to Western scientific understandings of the environment.

Conclusion

Acoma Pueblo community members maintain a direct relationship with their local environment and geologic framework. The Sharing/Learning Program we implemented at Acoma Pueblo was focused on discussing the intersection of Western scientific geologic concepts in tandem with Acoma Pueblo community member's use of earth materials. By using an Indigenous Research Framework, our Sharing/Learning Program created a unique learning environment where

participants shared information with each other informally. This freedom in discussion encouraged participants to contextualize the Western scientific concepts presented during the Sharing/Learning Program with their unique cultural experiences and values within the Acoma Pueblo community. Throughout the Sharing/Learning Program, Acoma Pueblo behavioral norms dictated that the elders participating in the program maintained a striking presence, often guiding the discussion back to Acoma cultural values and history. Analysis of the closing interview of the participants identified geoconnections that represent a multitude of connections between Traditional Knowledge and multiple scientific disciplines. It is our intent that the information contained within this manuscript should be maintained by the Acoma Pueblo community and all educational materials derived from this information should be approved by the Acoma Pueblo community's Officials.

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GEOCONNECTIONS AND PERCEPTIONS OF GEOSCIENCE AMONG UNDERGRADUATE STUDENTS LIVING ALONG THE YAKIMA RIVER IN WASHINGTON STATE

Introduction

Geology has one of the lowest participation rates for underrepresented minority students in all of the sciences (Riggs, 2004; Beede et al., 2011), and enrollments in geology programs in US universities and colleges have long fallen well short of predicted employer needs (Gonzales & Keane, 2010). Growing the size of geology programs is critical for the future of the discipline, as well as to meet societal needs, and this requires strategies that make connections to the relevance and excitement of geology for all students. "GeoConnections" is a mixed methods research project designed to evaluate the idea that enhancing the cultural relevance of introductory geology activities at the undergraduate level will promote and increase students' connections to geoscience concepts. This is a necessary prerequisite to increasing enrollments in geology programs, especially for students from underrepresented groups (Dahl, 2016).

The GeoConnections idea was evaluated by targeting cultural connections to specific groups of undergraduate students through developing place-based, culturally-relevant geoscience education modules (GEMs) focused on increasing Indigenous students' interest in geoscience. These modules were implemented at a private university on the lands of a federally recognized Indigenous community in the state of Washington. Growing the involvement of Indigenous students in the geosciences is a high priority for a number of reasons, including the clear connections between Indigenous cultural values and the Earth sciences, and the strong needs for Indigenous geoscientists in managing natural resources on their own lands in ways that remain respectful of cultural values of specific Indigenous communities (Smith, 1999; Riggs & Riggs, 2003).

There is a major disconnect between scientific concepts that are taught in K-12 and undergraduate programs and the cultural knowledge that many underrepresented students receive in their home environments. Research that comes from exploring the connections that diverse students make between Western science and their traditional culture (the term "geoconnections" will represent these connections throughout the rest of this paper) can provide new perspectives

into strategies to contextualize geology instruction to the cultural contexts of any group of learners (e.g. Brayboy, 2008; Chilisa & Tsheko, 2014). GeoConnections advances this concept while providing particular insight into teaching geology to Indigenous students whose traditional cultures are often environmentally-based with many direct connections to social community structures and values. This project is the beginning of a long-term effort aimed at understanding how different cultures view and integrate geologic concepts with the traditional cultures that form the base of their personal identity, and using this understanding to help a wide range of instructors adapt educational modules to enhance the cultural connections of their geology and other science courses. Making these connections for diverse groups will also allow newly produced geologic information to be understood by a much larger segment of the population, which will strengthen the political decisions being made by these groups regarding land use, natural resources, and climate change.

Culturally relevant geoscience education has attracted increasing interest within the education community because degree-attainment statistics point clearly to an inequity between students from dominant groups and underrepresented students (Lynch, 2001; Ladson-Billings, 2009), especially Indigenous students (Barnhardt, 1997; Lee, 1997; Aikenhead & Jegede, 1999; Smith, 1999; Czujko, 2010; Beede et al., 2011). Many Indigenous students, however, see no connection between Western science and the goal of preserving their cultural identities (Cajete, 2000; Smith, 1999; Reano & Ridgway, 2015). Ironically, many Indigenous students eventually learn that a mastery of science and engineering can be of enormous benefit in helping to maintain their communities and thus empower efforts to preserve their cultural identities (Smith, 1999).

While some research has been conducted to help understand Indigenous understandings of geoscience (Semken & Morgan, 1997; Gibson & Puniwai, 2006; Semken & Freeman, 2008; Palmer et al., 2009), less emphasis has been placed on recognizing common connections Indigenous students make between their traditional cultures and Western science (Garcia & Ahler, 1992; Zwick & Miller, 1996; Cleary & Peacock, 1998). Thus, a key purpose of the intervention described in this chapter is to identify connections undergraduate students make between introductory geology concepts and their everyday interactions with the earth. This was achieved through the use of a “sense of place” survey instrument (Appendix B) as well as semi-structured interviews with participants after implementation of the geoscience education modules (GEMs). The term used in this dissertation to describe connections between geology and the culture of the

participants is “geoconnections”. The impacts of using these geoconnections as part of modified GEMs that are “place-based” in the sense that they connect to the cultural-as well as geographical-sense of “place” experienced by students (Semken, 2005; Semken & Freeman, 2008; Semken et al., 2009) can then be examined. These GEMs were designed to avoid shortcomings in traditional (i.e. generalized, de-contextualized knowledge-transmission) teaching and pedagogical techniques, and to radicalize pedagogical practices used by educators of underrepresented students, especially Indigenous students. The GeoConnections and GEM designs were both informed by socioTransformative constructivism, a theoretical framework based on multicultural education theory and social justice theory. Tribal Critical Race Theory was also used to contextualize the generalizable aspects of sTc for the specific Indigenous community where GeoConnections GEMs were implemented.

Methodology

Theoretical Framework

The theoretical perspective used as the lens for this study is a combination of the sociotransformative constructivism (sTc) framework and Tribal Critical Race Theory (TribCrit) (Rodriguez, 1998; Brayboy, 2005). The sTc framework puts forth that knowledge is socially constructed, “is mediated by cultural, historical, and institutional contexts”, and also creates a way for participants to engage in meaningful dialogue concerning their local communities (Rodriguez & Berryman, 2002; Zozakiewicz & Rodriguez, 2007). This framework is also amenable to recognizing culturally sensitive information that many frameworks do not address (Riggs, 2004). For instance, sTc views teaching and learning as political acts, requiring recognition of the power dynamic between majority and minority participants in the educational system (e.g. teachers and students) (Rodriguez & Berryman, 2002). Power dynamics are not explicitly addressed as influencing the dynamics of learning environments within individual or social constructivism (Rodriguez, 1998).

In order to be aligned with sTc, there are four major components necessary: dialogic conversation, authentic activities, metacognition, and reflexivity (Rodriguez, 1998, Rodriguez & Berryman, 2002). Every component of this theoretical framework had an important role in the development of the GEMs created for GeoConnections. The dialogic conversation component is

a way of creating a respectful space in the learning environment so that students are able to speak freely, with each other and the instructor, without fear of reprimand or belittlement and is necessary to align with sTc's stance on the social construction of knowledge (Rodriguez, 1998). The dialogic conversational space is not free from tension, so respect for other is extremely important to maintain a productive educational environment.

Authentic activities must be culturally relevant in order for learners to be able to scaffold previously held knowledge (i.e. cultural knowledge) with the new concepts being taught in the classroom. Without a meaningful context, learners have been shown struggle with knowledge construction (Russell, 2014).

The metacognition component requires student learners to question why certain knowledge is being taught (Rodriguez, 1998). This also includes omitted information that may be part of an underrepresented student's cultural knowledge but that is not necessarily part of the instructor's previously held knowledge (e.g. the Pueblo Revolt of 1680 is rarely mentioned in New Mexico history classrooms even though it is one of the most significant events in New Mexico history).

Finally, reflexivity describes the way that students put their particular educational experience into a much broader perspective (Rodriguez, 1998). This enables students to understand why certain information is deemed necessary for their education while other topics are inaccessible in the normal course of education. It is in this reflection that historical, political, and institutional contexts are realized and opportunities for students to transform their educational experience are created (Rodriguez, 1998; Rodriguez, 2008). These four components of sTc (Rodriguez & Berryman, 2002) are collectively used to create agency for participants in educational activities. Agency refers to the conscious role that we choose to play in spreading beneficial change for everyone, but especially for disadvantaged individuals and groups of people (Rodriguez & Berryman, 2002).

TribCrit describes a theoretical framework where historical contexts of power, especially between Indigenous groups and non-Indigenous groups, and hegemonic control are recognized and actively discussed throughout pedagogical practices (Brayboy, 2005; Zywicki, 2013). Indigenous communities continue to experience colonialism and its negative after-effects over the past several hundred years as they have survived genocide and endured forced removal from their homelands/territories. Many Indigenous communities continue to protest the denial of rights to practice their Traditional cultures freely and without consequence. Acknowledging this historical

context of Indigenous peoples in the United States is necessary to provide Indigenous students an equitable learning environment that can also provide them the agency to transform their communities through the use of Western scientific geologic concepts. TribCrit is a necessary addition to our project framework because it specifically addresses "American Indians' liminality as both legal/political and racialized beings" (Brayboy, 2005), which is a vital perspective when working with complexly situated sovereign nations. The full scope of TribCrit addresses nine tenets of which the details can be found in (Brayboy, 2005), but the most critical tenets of TribCrit that are relevant for this project are: colonization is endemic to society; the meaning of the concepts of culture, knowledge, and power can be uniquely understood through an Indigenous lens; and Tribal philosophies, beliefs, customs, traditions, and visions for the future are necessary to understand the lived realities of Indigenous peoples (Brayboy, 2005).

Our approach for this project combines TribCrit with sTc so that the specific historical contexts of Indigenous students are considered and actively integrated into the GEMs while at the same time allowing these students to impact their educational experience and transform that experience into something that they, the students, feel will benefit themselves and their community. The overarching goal of this research project is to determine if an approach using Indigenous research frameworks has a significant and observable impact on students' connections to geoscience conceptions and careers. Longer term, a longitudinal study in which the pathways of Indigenous geoscience students is explored to determine if the geoconnections within the GEMs were influential in students' decisions to pursue geoscience degrees could prove very useful.

Participants & Context

The Pacific Northwest of the United States is home to many Indigenous communities who have been there since time immemorial. GeoConnections was implemented at a private, four-year institution with a higher enrollment of Indigenous students than other universities. This is primarily due to its location, being situated within the boundaries of a large Indigenous community. Indigenous students were not actively recruited to take part in the course, but instead the study relied on the demographics of the institution as a way to ensure a relatively high enrollment of Indigenous students.

There was a total of 13 participants in GeoConnections. 8 were male and 5 were female. The concept of Indigeneity is complex. In our context, it is further complicated by the

juxtaposition of multiple Indigenous cultures to the campus on which our intervention took place. The definition of Indigenous used in this manuscript follows that of recent work by other Indigenous scholars which emphasize that the term "Indigenous" refers to "a community of peoples sharing intergenerational ancestry and cultural aspects with original (pre-colonial) occupants of ancestral lands in a specific region of the world" (David-Chavez & Gavin, 2018).

GeoConnections took place during the Fall semester of 2017. This was a particularly turbulent time within the historical context of the United States. At the beginning of this semester the United States Department of Homeland Security began phasing out the program known as Deferred Action for Childhood Arrivals (DACA) (Department of Homeland Security, 2019). This political action created an environment where many non-majority students felt unsafe and insecure in their standing as rightful attendees of higher education institutions. Coupling this with an academic researcher asking students to sign Institutional Review Board (IRB) forms to be part of a study, specifically designed to call attention to non-majority cultures, had the potential to create an instant air of distrust among the potential participants. Because of the small size of the institution, the instructor of the course was very aware of the political climate and the complexity of how this situation could impact students from various backgrounds enrolled in her class.

Methods

The primary research question for GeoConnections is "What connections do undergraduate students make between geoscience concepts and their cultures after participating in place-based, geoscience education modules developed using TribCrit + sTc?". This research question is exploratory. The initial step for GeoConnections was to identify cultural connections that were then used to develop the place-based GEMs. In our context "place" is a rich concept that includes not only the traditional geographic location, but also the cultural "place", reflected through connections with abstract cultural information such as language, art, and societal relationships (Cajete, 2000; Semken & Morgan, 1997; Semken, 2005; Semken & Freeman, 2008; Semken et al., 2009). Initial geoconnections were identified through focus groups during the Spring semester of 2017 that were conducted with instructors at the host institution who were currently teaching introductory geoscience courses, Indigenous students from the communities near our partner institution who were enrolled in introductory geoscience courses, and representatives from local

Indigenous communities near our partner institution who are stakeholders in the content of the GEMs that were being developed.

The theoretical framework (TribCrit + sTc) for the GeoConnections project declares that the geoconnections that were developed into GEMs must have significance and relevance for the Indigenous communities for which GeoConnections was developed for. The purpose of having focus groups is to ensure that the needs of the communities remain paramount throughout the implementation of the GeoConnections project. The lead author (Reano) conducted the focus groups using his previous experience working with underrepresented populations as well as information from various Indigenous research frameworks to help guide the focus group discussions in a respectful and inclusive manner.

Three geoscience education modules (GEMs) were developed from the initial geoconnections identified through the focus group interviews and were implemented during an introductory environmental science course during the 2017 Fall semester. A sequential transformative design was used for a mixed methods assessment of the impacts of place-based, geoscience educational modules on students' connections to geoscience concepts as well as their connection to the Yakama community. A sequential transformative design consists of the collection of quantitative and qualitative data with a strong theoretical perspective that guides the study's research questions (Creswell et al., 2003). However, because the modules took place over a week of class time, some students were absent for the pre- or post-assessment and/or some of the module activities. A sequential transformative study design calls for the integration of the qualitative and quantitative data during the interpretation phase of the study after both datasets have been collected (Creswell, 2003). This type of mixed methods study treats the qualitative and quantitative data equally so that both sets of data are of high quality and the sequential order of data collection enhances the study's findings (Creswell, 2003).

The assessment began with a quantitative data collection using a modified, validated survey instrument before implementation of the place-based educational module and the exact same instrument was used after implementation of the modules. The survey instrument was modeled on another instrument that was designed to detect changes in students' sense of place (Young, 1999; Williams & Vaske, 2003; Semken & Freeman, 2008; Ward et al., 2014). Sense of place refers to the emotional, spiritual, and other affective responses to a particular geographic location experienced by people (Semken, 2005; Semken & Freeman, 2008; Semken et al., 2009). The sense

of place instrument is designed to measure place attachment (Appendix B). Place attachment refers to how closely connected individuals feel towards a particular place (Semken & Freeman, 2008).

The pre/post-sense of place assessment used a 5-point Likert scale on which participants indicated their attitudes and perceptions regarding geology and the Yakama community before and after implementation of each GEM. The questions from the place attachment component of the sense of place survey were quantitatively analyzed using a *t*-test analysis to statistically determine major impacts on participants' perceptions of the Yakama community.

After analysis of the quantitative data, semi-structured focus group interviews were conducted with all willing participants, which included both Indigenous and non-Indigenous participants. Further information about the demographics of the interview participants is withheld because the release of more information could potentially result in the identification of the participants. Audio recordings of these interviews were transcribed and qualitatively analyzed using thematic analysis (Sandelowski & Barroso, 2007; Houlton, 2010) in order to identify and explore student perceptions and conceptions of environmental science, geology, geoscience concepts, geoscience careers, and the relevance of geology and/or environmental science to their daily lives.

Originally, the mixed methods approach was supposed to allow the researchers to hone in on particular aspects of the GEMs that have the greatest perceived impacts. However, the quantitative results were not statistically valuable, primarily due to the low participant numbers. Additionally, due to time constraints, the qualitative interviews were not able to be held until after the second module had been implemented. Therefore, our qualitative results do not provide insight beyond student reflective conceptions of geoscience before taking the introductory environmental science course. These situational complexities prevent us from integrating the quantitative dataset with the qualitative dataset in a meaningful way. The analysis presented here focuses primarily on the qualitative dataset.

Geoscience Education Modules

Backward design was used to align the goal of creating a more holistic educational experience with the specific activities developed in each of the GEMs (Wiggins & McTighe, 1998; Michael & Libarkin, 2016). Each of the activities in the GEMs was designed to achieve one of

the four components of sTc. Once a particular aspect of sTc was chosen, TribCrit was used to contextualize the activity towards an Indigenous perspective. Since the host institution is located on the traditional territory of the Confederated Tribes and Bands of the Yakama Nation, the Yakama perspective was privileged throughout the GEMs. As a final step, non-Indigenous perspectives from the local community (e.g. Western scientists and researchers, local business owners) were added to ensure that the multiple perspectives present in the classroom were also represented in the GEM activities.

Columbia River Basalt (CRB) Module

Sequestering carbon dioxide as a climate change mitigation strategy is becoming a more common practice globally as climate change effects become more visible and apparent to the global population. When many people think of sequestering carbon, they often are considering how a stable climate can benefit local environments and their inhabitants. Fewer people consider the geological and environmental conditions that are necessary for carbon sequestration to be successful. Carbon sequestration involves identifying competent, weathering-resistant rock formations that are able to encapsulate the carbon with minimal degradation. Geological sequestration of carbon also requires some place to leave the enclosed carbon undisturbed, potentially for extended periods of geologic time.

The CRB module was developed around current research describing an innovative technique to sequester carbon in a solid phase (Matter & Kelemen, 2009; McGrail et al., 2017) as a way to mitigate climate change. The first day of the CRB Module was focused on introducing students to Indigenous and Western scientific perspectives of the Columbia River basalts and the impacts of climate change in the Pacific Northwest of the United States.

The second day began with a discussion about "The Wallula Basalt Pilot Project". The Wallula Basalt Pilot Project is a recent advance in research concerned with carbon capture and storage (CCS). The textbook used during the class defined CCS as "The removal of carbon from fossil-fuel combustion and storage of the carbon, usually underground" (Raven et al., 2015). During the class, the term "carbon sequestration" was used to mean the same thing as CCS, although many people associate carbon sequestration with climate change and global warming, which can have geopolitical implications for many communities.

The most predominant type of CCS reported by the media are projects that inject supercritical CO_2 into sandstone formations using wells that were originally drilled to remove economically large reserves of hydrocarbons and/or natural gas. This is common practice because sandstones are found in many places on the surface of continents and scientists can also measure how much volume could potentially be "refilled" by monitoring oil/natural gas production. However, new research has shown that long-term stability of sequestered carbon might also be achieved by crystallizing the carbon into carbonate minerals (Matter & Kelemen, 2009; McGrail et al., 2017). This is achieved through interactions between supercritical CO_2 fluids that are injected into basaltic bodies.

For the lab portion of the CRB module, the main focus was on the geochemistry of basalt minerals and their reactions with carbon dioxide, which form carbonate minerals (Matter & Kelemen, 2009; McGrail et al., 2017). Researchers at the Lamont-Doherty Earth Observatory of Columbia University (Matter & Kelemen, 2009) and the Pacific Northwest National Laboratory (McGrail et al., 2017) have advanced CCS technology by conducting experiments to demonstrate how in-situ geochemical reactions between supercritical CO_2 and basalt mineral assemblages promotes the crystallization of carbonate minerals. This geochemical process is one potential solution for reducing atmospheric CO_2 levels to decrease the effects of global climate change.

Scientists commonly use chemical equations to describe reactions between different chemical compounds. The first part of the CRB module focused on the specific geochemistry needed for atmospheric CO_2 to be dissolved into water and recrystallized as a carbonate mineral, such as ankerite. The second part of the lab was a graphing exercise. As part of their experiment, McGrail et al. (2017) measured $\delta^{18}O$ and $\delta^{13}C$ values within carbonate minerals found in the Grande Ronde Basalt both pre and post-injection of 1000 metric tons of supercritical CO_2. Participants graphed and plotted the data points for the pre-injected carbonate $\delta^{18}O$ and $\delta^{13}C$ values, the data points for the post-injected carbonate $\delta^{18}O$ and $\delta^{13}C$ values, and finally the $\delta^{18}O$ and $\delta^{13}C$ values of the supercritical CO_2 liquid that they injected into the Grande Ronde Basalt. For the final part of the CRB module, participants were asked to consider holistic development plans that could hypothetically be used as a framework to begin discussions with the various stakeholders from the local community by outlining various benefits and drawbacks of pursuing this new CCS technology in the local area (learning objectives for all modules is included in Appendix C).

Yakima River (YKR) Module

> "Water is the very fabric of life for the Yakama Nation. Its importance cannot be overstated. Water is central to our religion, our culture, and our heritage, and it is essential to our health and our economy. The snow and the rain feed our streams and wetlands, which quench our thirst and sustain our fish, wildlife, foods, and medicines. Water is all things to all that are living all yet to be born." --(*Climate Adaptation Plan for the Territories of the Yakama Nation, 2016*)

The YKR module is an example of active learning pedagogy (McConnell et al., 2003). For this module, emphasis was placed on Indigenous perspectives of the Yakima river and its impacts on the Yakama community. Rather than positing our own ideas of the what the cultural significance of the river is to the Yakama community, quotes were shared from the Climate Adaptation Plan for the Territories of the Yakama Nation (2016). Participants were also provided with the complete document of the climate adaptation plan and asked to read all of it prior to the implementation of the YKR module. This climate adaptation details specific climate change impacts that are expected to affect the Yakama community. Also included in the adaptation plan are key task items that the Yakama Nation has prioritized as necessary to mitigate climate change effects within the Yakama community.

The first day of the YKR module focused on geomorphic features of rivers. Google Earth was utilized to view these geomorphic features such as oxbow lakes, mid-channel bars, meanders, and channel shapes. Participants in the lab were also directed to focus on where the river intersected with highways and other man-made features that impacted the shape of the river. For the lab portion of this module, stream tables were used to demonstrate how rivers form and the resultant geomorphic features that are created as a function of slope, vegetation, bedrock composition, and water flow velocity. Students manipulated these variables over the course of a 3-hour lab. During this lab, the concept of Traditional Ecological Knowledge (TEK) was introduced and following quote (Yakama Nation, 2016) was shared to help participants consider the cultural value of the Yakima river to the Yakama community:

> "Salmon are perhaps the most important of our First Foods. According to our creation story, the salmon was the first to agree to care for the Indian people. The First Foods nourish us, and we must protect them and the habitats that support them. We therefore have a reciprocal relationship with salmon. The salmon's spirit has not changed over the years; what has changed is the environment that once sustained that powerful spirit.
>
> When we think about salmon in our cultural context, we think of a broad category of important species that includes steelhead, lamprey, freshwater mussels, trout, and other fish. We understand that bringing back our salmon, lamprey, and other fish important to the Yakama Nation will require us to restore a variety of important habitats that they need; this has become a high priority."
>
> --(*Climate Adaptation Plan for the Territories of the Yakama Nation, 2016*)

During this module, Yakama community members entered the classroom and offered guidance on the required habitats for salmon. These community members helped participants identify different areas of their stream table setups that would be suitable habitats for salmon. These areas were recorded on the notes that participants were required to document as part of the lab.

Policy and Communication (PAC) Module

The PAC module was developed in response to research calling for a more holistic approach to geoscientific training. The American Geosciences Institute released information (Houlton, 2015) showing that geology graduates were over trained in technical geoscientific analytical skills. At the same time, these graduates self-identified as being underprepared in non-technical skillsets that were needed in the jobs they took after graduation. To address these concerns, the third and final module was developed to focus on communication and policy.

Our approach involved first identifying individual communication patterns using a personality diversity indicator (PDI) and E-colors (Equilibria, 2019). Equilibria was founded in 2004 by four individuals from the oil and gas industry (Equilibria, 2019). It was designed to help individuals realize how their preferences for communication can be used in ways that enhance interpersonal communication skills, understand more about other individual's personalities by building better relationships, and also to work more efficiently (Equilibria, 2019). The instructors took a substantial amount of time to talk with the participants and explain that our use of E-colors was primarily for reflecting on interpersonal communication. The PDI involves a set of 35 questions that takes about 15 minutes to answer. Based on the answers to the questions, participants are grouped into one of 12 possible communication styles. The instructors for the course further explained that these communication styles can change over time and are not meant to be all-encompassing judgements of individuals and their personalities.

Interpersonal communication (learning about how other people communicate) is part of intercultural communication (learning how other cultures communicate). Both of these concepts require us to consider what is important to other people and other cultures (e.g. What are their values?). Environmental Science (as well as all other sciences) requires communication between different people. Sometimes information needs to be written, but many times scientists have to talk to another person about the information they are trying to share. Well-developed communication skills help the information become more easily understood because more people (e.g. non-scientists) are able to comprehend the scientific information that is being shared.

This is relevant for undergraduate students because they have to communicate with their instructors, their mentors, school administration officials, as well as their family and other businesses and friends they might encounter on a daily basis. Sometimes, while taking part in all of these interactions, people do not have time to reflect on our own emotions regarding specific situations, equally we tend not to think about how others might perceive ourselves during these multiple interactions. This is especially important when we are communicating ideas about Traditional Ecological Knowledge and/or Western Science. As scientists, we need to understand what values our audience holds, if we are actually interested in convincing them that the information that we are sharing is valid.

For the second part of the module participants were asked to identify people who they recognize as being part of their support network. The instructors of the course used a visual tool

developed to serve individual needs of students in both informal and formal settings (Glessmer et al., 2015). This part of the module was intended to make explicit those connections that students have to provide them with different types of support such as: emotional support, professional development, career opportunities, etc. Included in this portion of the class was an opportunity for the students to reflexively recognize how their academic experience could be impacted by the social capital they have accrued from developing their support networks.

For the lab portion of this module students chose a particular chapter from the Climate Adaptation Plan for the Territories of the Yakama Nation (2016) and addressed one of the task items delineated at the end of that chapter. Then the participants created and proposed an action plan that directly addressed the task item. The action plans were created in groups and each group had to develop a support network for their proposed action plan. Students spent the first part of lab brainstorming over which task item they wanted to address, and then had to name actual people (e.g. scientists, politicians, community members) that they would approach to help them put their action plan into practice. At the end of the lab, each group presented their action plan and supporting materials (e.g. powerpoints, brochures, schematic diagrams) to the rest of the class and explained who the stakeholders are in relation to the task item they chose. In addition, each group was asked to explicitly mention why the people they identified in the support network for their action plan would need to be involved to successfully implement their action plan.

Results of Analysis

Quantitative Results

Figure 5 details the results of the *t*-test used to analyze the place attachment portion of the sense of place survey. Only the participants who completed both the pre-assessment and the post-assessment for a particular module were included in the quantitative analysis. Based on these criteria, there are 11 participants for the CRB module, 9 participants for the YKR module, and 11 participants for the PAC module. As explained earlier, these low participant numbers impacted the statistical generalizability of our quantitative analysis.

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PAQpreCRB	38.6364	11	8.88001	2.67742
	PAQpostCRB	40.2727	11	8.54507	2.57643
Pair 2	PAQpreYKR	42.5556	9	9.19390	3.06463
	PAQpostYKR	42.1111	9	9.76530	3.25510
Pair 3	PAQprePAC	40.8182	11	10.73143	3.23565
	PAQpostPAC	42.6364	11	7.33857	2.21266

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	PAQpreCRB & PAQpostCRB	11	.883	.000
Pair 2	PAQpreYKR & PAQpostYKR	9	.985	.000
Pair 3	PAQprePAC & PAQpostPAC	11	.802	.003

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	PAQpreCRB - PAQpostCRB	-1.63636	4.22546	1.27403	-4.47507	1.20234	-1.284	10	.228
Pair 2	PAQpreYKR - PAQpostYKR	.44444	1.74005	.58002	-.89308	1.78197	.766	8	.466
Pair 3	PAQprePAC - PAQpostPAC	-1.81818	6.53939	1.97170	-6.21140	2.57504	-.922	10	.378

Figure 5. Paired sample *t*-test results for the geoscience education modules in GeoConnections. All of the p-values (labelled as Sig. (2-tailed) under the "Paired Samples Test" heading in the figure) are greater than .05, indicating no distinguishable statistical difference between the pre- and post-assessment results from the sense of place survey.

As Figure 5 shows, the p-values for all of the implemented modules (Pair 1, CRB module=.228, Pair 2, YKR module= .466, Pair 3, PAC module= .378) are greater than .05. The null hypothesis for the *t*-test in our context is that the true difference in mean values between the pre- and post-assessment is equal to zero. Because the p-values are greater than .05, the null hypothesis fails to be rejected. In the context of GeoConnections, this means that we are unable to distinguish a difference between the pre- and post-assessment responses for the place attachment portion of the quantitative analysis. However, this should not be taken to mean that the GeoConnections modules had no impact on the participants. The following section presents the qualitative results and highlights the participants' feedback concerning how the modules impacted how they feel about the Yakama community on an individual basis.

Qualitative Results

The qualitative results presented here are the product of a thematic analysis (Sandelowski & Barroso, 2007; Houlton, 2010) used to identify and explore student perceptions and conceptions of environmental science, geology, geoscience concepts, and the relevance of geology and/or environmental science to their daily lives. The data were collected from interviews of eleven participants during the second half of the Fall 2017 semester. All interviews were conducted after implementation of the second GEM (YKR module). A timeline of the Fall 2017 semester including when the modules were implemented, when the sense of place surveys were conducted, and when the interviews were conducted is detailed in Figure 6.

Timeline for GeoConnections Data Collection during 2017

March 22 - 28

Focus group interviews conducted with faculty, students, and community members.

June 27- July 4th

Focus group interviews conducted with faculty, students, and community members.

August 21st

Classes begin at host institution

September 2-7

Darryl was introduced to the class. Initial sense of place assessment administered.

October 9-13

Columbia River Basalt (CRB) module implemented.
Sense of place assessment pre- and post-module implementation.

October 30- November 3

Yakima River (YKR module) implemented.
Sense of place assessment pre- and post-module implementation.
Five interviews conducted with participants.

November 12-17

Policy and Communication (PAC) module implemented.
Sense of place assessment pre- and post-module implementation.
Three interviews (two of these were follow-up interviews) conducted with participants.

November 29- December 1

Six interviews (one was a follow-up) were conducted with participants.

December 3rd

Classes end at host institution

Figure 6. Timeline of data collection at host institution for GeoConnections during 2017.

Four major thematic concepts (communication, environmental justice, agriculture, and conscientiousness) were identified within the transcripts of the semi-structured interviews of participants regarding their perceptions of geosciences. This section will briefly define each theme which will be followed by the examples of each theme. The second part of the results section will provide additional context for the questions that provoked these responses in the participants.

The first theme is “communication”. This was defined as the mentioning of the sharing of knowledge, whether formally or informally. Some participants described instances of sharing

knowledge with family members, discussing geoscience topics with instructors of their classes, and also sharing knowledge with other students and community members informally.

Examples of responses coded as communication. Brackets and bolding were added by the researcher for clarity:

> "It's about **sharing what you know**. **Sharing what I know** and just basically, I feel like that's basically the biggest way they [my major and geoscience] connect."
>
> --Participant E

> "I think the **more education** that is out there, the better. The **more people learning about it**, even with our class. Everybody who goes out to do their own separate ways, **we now have the knowledge that we can hopefully pass on to others**."
>
> --Participant C

> "**This class made me ask people who have been here for a while about global change**, and 'Are you afraid of global warming and stuff like that?' And to see the reactions of people, like 'Hey, when I was living here in the '70s certain things happened.' And to see that, since I've been here there has been change."
>
> --Participant M

The second theme is "environmental justice". This theme was used to highlight instances where participants directed attention towards situations where pollution and/or contamination of toxic substances were impacting the environment. Many of these instances were directly tied to health concerns expressed by the participants.

Examples of responses coded as environmental justice. Brackets and bolding were added by the researcher for clarity:

> "I think **the use of pesticides and how it's in the water and how it's in the ground, and people aren't aware of it.** That's one of the major things that's concerning to me, because **people don't know how contaminated their water is, and people are unaware of it**.
>
> --Participant X

> "It saddens me when we go to streams or rivers that we were used to swimming in, and we're like, **'Brown water, don't want to get near it. Don't trust it.'** Do you know what I mean? It's [the importance of geoscience to the community] very important, I guess, because it's like **if something's contaminated, you can't get near it**, and it's just ... I know we have a lot of beautiful natural resources, and that's the reason I like this area so much, but it just seems like **we need to be more conscious of what's going on and what we're putting out there.**"
>
> --Participant M

> "I don't think I had considered exactly the ways that that was having a negative effect on the environment whereas **now I see farmers laying down white powder in the fields and I think a little bit more**, a lot further into that, like what is this, **this fertilizer that's going to run off into the streams and end up in my kitchen**."
>
> --Participant C

The third theme is "agriculture". This theme was used to identify those instances where participants mentioned the agriculture industry, agriculture processes and practices, as well as food products produced by the agriculture industry.

Examples of responses coded as agriculture. Brackets and bolding were added by the researcher for clarity:

> "Well, I feel like it's very important, because ... Like I said, just look around, it's everything. **We depend on farms**, all types of different farmings, and **we just use it everywhere**, and especially here… **that's pretty much the life here**. So I feel like **everybody depends on it in some way**."
>
> --Participant R

> "Like very important because, I mean, like **the whole community is like around, like agriculture**. It's like **most of the like businesses are agriculture businesses**."
>
> --Participant L

> "I think it's very important, because **there's a lot of people farming here**, especially where we're at, **they have the hops, and the apples, and the corn.** I think it's really important here in our community."
>
> --Participant S

> "That makes me think about the **agriculture** around here and how we have, **everything surrounding us is pretty much apples**. My family grew up doing that kind of thing, and that's the first thing that comes to mind when I think of **agriculture** and geology and how the land is shaped around here. That's the first thing that comes to mind."
>
> --Participant X

The fourth theme is "conscientiousness". This theme was used to describe instances where participants expressed newfound awareness of their environment, their relationship and/or impact on the environment, and environmental hazards. This theme was also used to identify responses in which participants connected geoscience concepts to real-world situations outside of their local community.

Examples of responses coded as conscientiousness. Brackets and bolding were added by the researcher for clarity:

> "I feel like it's very important cause it can lead to, it could be **the difference between making a smart move or a bad move that could affect not only whatever it is that they're building there but the surrounding area**, so like **you can't just start building houses too close to a lake or to a river cause then they might fall over**. Or you can't put them too close to the road, the I82, cause there's traffic that goes really fast and **you don't want to risk lives**.
>
> --Participant P

> "Think it's [geoscience] like **a lens to look into the world**, and think about like. Not just, you know I come to school or this is what I'm doing. But, also **to think about nature**, so **it's kind of like a lens to view the world differently**.
>
> --Participant B

> "So, once you start seeing things like that [Indigenous people talking about oil spills], and you literally see the emotion on people, **it kind of becomes more real**. I guess **the concern of the environment kind of increases a little bit more**, so I feel like definitely, it's increased, you're more aware of those things and, like I said, **not just in your little world here in the community that we live in, but also in the same country, Alaska's still in the United States even though it's hundreds of miles away**, and still, once it's affected it could be irreversible. So, basically, **it brings more real concern about the environment**, and once we heard it, it might be irreversible, and sadly some people learn the hard way. By that time it might be too late, so, yeah.
>
> --Participant E

These four themes were reflected in multiple responses to all of the questions pertaining to geoscience that were posed during the semi-structured interviews to different participants. In order to provide a more holistic description of the geoconnections that the participants acknowledged during the interview the next portion of the results section will focus on the participants' responses to specific questions posed during the interviews. This context will provide a more direct throughput of geoconnections expressed by the participants during the interviews. Brackets and bolding within the quotes have been added by the researcher during analysis.

Question 1: Do you see connections between your major and geoscience?

> "I'd probably say the **environmental laws that are enforced** due to like stopping deforestation because it could potentially kill the Amazon Rainforest. Or the thing about the owl here in Washington when logging was just a big industry, things are set in place to prevent something from happening, **whether people like it or not**, it has to do - it's for the environment."
>
> --Participant P, criminal justice major

Participant P, a criminal justice major, has made a direct connection between environmental laws and two distinct examples of protections that are meant to protect non-human entities within the environment. One example is about deforestation in the Amazon Rainforest and the other example is related to local environmental protections put into place to protect northern spotted owls. Neither example was part of the GeoConnections GEMs, however they were mentioned during class discussions during the semester. The participant also says that not everyone will "like" the laws. Participant P is using reflexive thinking patterns to connect similarities between local and global environmental protection efforts. Additionally, the participant is also considering the different perspectives of the industry as well as people who would put the environment's protections as a priority. These examples provide insight for future instructors of the environmental science course to contextualize geoscience content for other criminal justice majors.

> "Well, the connections I see is, it's about sharing what you know. Sharing what I know and just basically, I feel like that's basically the biggest way they connect. In education…**you're basically gonna share what you know with somebody else, and you're gonna do it in your own particular way**, and so people have different ways of doing it, and I think for me, teaching in high school or middle school, that would be my way. But I know some other people do it by writing papers, writing books, experiments, but for me, the biggest way that they connect, it would be **sharing their knowledge and putting it out there**. I guess the difference would be the way that you do it."
>
> --Participant E, education major

Participant E, an education major, focuses on communication practices as a relevant part of geoscience that is connected to their major. Participant E says that sharing knowledge is an important part of their major, but that the way that the knowledge is shared is also important because "people have different ways of doing it". The participant wants to share knowledge by teaching in high school or middle school, but also values the sharing of knowledge in the form of writing papers, writing books, and doing experiments. The participant is using metacognitive thinking practices to realize that although pedagogical practices of teaching and scholarly output of geoscience research are different deliverables, the focus of these practices is the same: sharing scientific knowledge with others.

> "Yes, because in sculpting, using certain type of minerals, have ... What is it, flux? They can make a ... **When you cook it, it makes the rock appear shiny.** So, in art, it's important to know which ones do that for when you're making a sculpture, what the end result is. Because **some of the colors are paints or minerals from the earth, create a matte-type look where you're looking for a shiny thing**, and that in geo science, it's important. Because my advisor nerds out, because he's like this rock geek. You know what I mean? So he

> likes to teach us. You know what I mean. But since I'm not really passionate about that yet, I haven't gotten there yet. But I guess, yeah it is ... **There is a connection, because we use clay and we use different types of minerals from different parts of the Earth**. He actually travels everywhere to get different rocks so he could fuse them together, so I guess there is a tie. **You could make something out of ... Like a career out of that**."
>
> --Participant M, fine arts major

Participant M is a fine arts major. They are describing the use of different earth materials to produce different effects in their artwork, especially sculpting. This is a great opportunity for environmental science instructors to scaffold information (e.g. natural paints, clay types) that the students are already exposed to in other classes and build on their previous knowledge to include geoscientific knowledge about those same earth materials. At the end of the quote Participant M also sees a connection to a career that lies at the intersection of geoscience and their fine arts major. This emphasizes the importance and relevance that the participant sees between their major and geoscience.

> "I've just always ... **Being outside is kind of my escape from noise** and I've always, even I remember in second grade I started clubs where we would catch insects and release them and toads. **I got the reputation as nature boy. I've just always had an interest in all things in the nature world I think."**
>
> --Participant C, environmental science major

Participant C is majoring in environmental science. Rather than asking the participant to describe connections between geoscience and environmental science, the interviewer asked the participant to describe how they became interested in their major. The participant's response focuses on an identity that they developed early in their childhood, practicing informal science. This led to the participant being identified by others as "nature boy". Their identity involving an interest in science persists to this day as they describe that "being outside is kind of my escape

from noise". If the participant is used to being outside in "the nature world" it seems natural that they would also choose a career that allows them to be outside as they work.

Question 2: What do you think is the most important connection between geoscience and the everyday lives of undergraduate students?

> "I think I'd want to talk about **the air**, and **climate change**. And how, with geology, you can study **the past climate**.
>
> --Participant A

> "Well, I'd point out how **everyday practices on today's time aren't necessarily friendly towards Earth** and if we keep going at this rate, it's going to, human, **all biotic life could basically be wiped out, and hopefully the person cares about that**. Usually they'll be, usually a person will be like, "Oh, the planet's going to die anyway so might as well do what you want," but **that's not necessarily a good way of thinking because it's just that thought right there doesn't really, puts you in a place where you're not really going to do anything about anything.** I guess, finding a way to make it important for the person. **Make something important that's not able to be seen.** Yeah."
>
> --Participant J

> "Probably the fact that from here and **the only really industry that is around here depends on crops, whether it's crops to eat or timber** or that's really it, around here. **You can either work on growing those things or cutting those things down or refining those things**. You get a factory job or you get to stack fruit or you go to school so you can be a logistics person to move them around. That's all there really is around here and when **you need environmental science and geology and that kind of understanding to make sure that all that works out smoothly**,

> because if you don't look at that data, if you don't have anyone to analyze that and you just ... you get the death pool pretty much…a death pool that's been stripped, stripped bare. So I think that's what it's important to keep data, **keep people analyzing around here in my community so you don't overuse or over strip the land of anything, not being able to grow anything ever again like we've seen before**."
>
> --Participant R

> "I feel like, **the way that we depend on the river, Yakima river, the rivers,** and just **how much we affect our planet**… As humans, we really do affect the environment. And **it's just not here in a little world**, little community, but it's also in some places where it's already been too late, and **we affect it in a really dramatic scale, and it's really bad**. So, I guess, kind of open our eyes a little bit more. If you think it's bad now, it could definitely get worse."
>
> --Participant E

In response to question 2, the participants focused on different aspects of geoscience. Participant A focused on climate change as something they feel is important to the daily lives of undergraduate students. Participants J and R focus on the negative effects of current environmental practices and their potential to disrupt the livelihoods of future generations. Both of these participants also recognize ways that attitudes about geoscience can help improve these situations. Participant J explains that finding ways to make geoscience relevant is important for people to value abstract geoscience concepts. Participant R voices the need for geoscience to be involved within industry settings so that the land remains productive, especially as natural resources are harvested. Participant E's response indicates a reflexive mode of thinking by considering the importance of the Yakima River to the local community. They then take the thought further by explaining that these relational dependencies exist elsewhere and that there is a time component involved that allows Participant E's community to learn from other communities where the environmental situation is worse from their perspective.

Question 3: Which of the geoscience education module activities taught you something that you did not know before?

> "I think **that carbon lab was really awesome**. That's a really amazing, **how you can turn the CO_2 into calcite**, plus around here don't they use calcite in the Ag? **So that would really help the Ag industry around here too**. I don't know, I'm really interested in that stuff, I would want to learn a lot more about the carbon stuff."
>
> --Participant A

> "For me, the most valuable was **the basalts, the rocks**… What I really found interesting on that whole thing was **how the CO_2 went into the basalt layers** where the rocks are, basalts, that [then] kind of crystallized. I was wondering like, **'What are the effects of having too much of that?'**…I think **more study has to happen before anything starts really going into a big scale, big scale project**…Yeah, more studying on the subject so you could find different facts about it and then present it to the public. Because once you find the facts, you got to find a way to **present it to the public** in order for it, I guess, **before you start passing laws** and stuff, right?"
>
> --Participant J

> "The **oxbow, the river**, pretty much all of the river. The terminology I didn't know about. Some of it I did, like **sedimentation** I think was a word that I didn't know before. There's a lot. **Carbon sequestration**, that never even existed inside the realm of mind **that we could take carbon dioxide out of the atmosphere and store it underground. That was a whole new concept to me**."
>
> --Participant C

Predominantly, participants expressed that the Columbia River Basalt (CRB) module was the most interesting for them. For Participants A and J, the interesting part was the geochemical process of turning atmospheric CO_2 into a solid carbonate mineral. Participant A elaborated in their response to connect these geochemical properties to potential uses by the local agriculture industry. Participant J also elaborates to voice a perspective that more studying should take place before the carbon sequestration technique should be legalized. Additionally, Participant J expresses that the public should also be informed about the scientific underpinnings of the carbon sequestration process. Participant C explains that they had previous knowledge of river systems, but they learned a new term related to that. More emphatically, Participant C expressed interest in the CRB module because carbon sequestration was an entirely new geoscientific concept for them.

Discussion

SocioTransformative constructivism has four explicitly stated components that are necessary for its implementation within educational activities (Rodriguez, 1998; Rodriguez & Berryman, 2008). These four components represent specific values that, by necessity, are at the forefront of how sTc engages with the common practices of the majority of teachers during interactions with students during class. The following sections will discuss these different components of sTc and how they are exemplified in the activities of the GEMs that have been developed as part of the GeoConnections project as well as in some of the interview responses from the participants.

Dialogic Conversation

Dialogic conversation refers to a community of participants coming together and having the confidence to voice their opinions without fear of ridicule simply for differences in communication styles (Rodriguez, 1998). This component of sTc does not imply that all participants will be completely comfortable all of the time, rather it is a space for engaging controversial ideas but with a respectful attitude for all participating parties. This entails a shared agreement among participants in the conversation to continually check their own perspective and allow themselves to take on the perspectives of other participants in order to come to a state of understanding (not necessarily agreement). It also involves being transparent and allowing

everyone to share their motivations for engaging in the conversation while not losing focus on the objectives of the topics that the participants are engaging with. This is a very complex process and typically involves a facilitator (e.g. teacher) continually finding linkages between what different participants (e.g. students) are trying to communicate while at the same time co-constructing knowledge by introducing new ideas (e.g. geologic concepts) into the conversation for all of the participants to engage with. The value in having a dialogic conversational space is the value of respect. For many Indigenous communities and their members, it would be impossible to have a shared understanding of any piece of knowledge without a demeanor of respect.

The activity that best reflects the dialogic conversation component of sTc is the Climate Change Activity within the CRB Module (learning objectives for all modules are included in Appendix C). In this activity, the participants spent thirty minutes watching videos of Indigenous community members, including Elders, talk about the environmental changes that affect their everyday ways of life. This included finding traditional healing herbs, the use of natural earth materials, natural hazard development, as well habitation patterns of animals that are culturally significant. The participants then watched twenty minutes of video including a video from the NASA website showing the global patterns of climate change and a different video showing the Integrated water plan for the local area (including Indigenous and non-Indigenous stakeholders).

The next part of the class was spent allowing students to write down their own opinions about what each video presentation's main message was, the evidence used by the presenters depicted in the videos to make their claims, and what level of authority the participants attributed to the speakers making claims in the videos. At the end of the activity participants conversed with a partner to talk about their different perceptions of each video. This was intended to give participants practice "taking on the perspective" of other participants in the class, as well as encouraging them to make connections between climate changes seen at the local level and climate change evidence seen at the global scale. This Climate Change activity also showed participants that even though all of the participants watched the same two videos, different people will interpret the message of the videos differently.

The following quote is an example of one of the student responses to which GEM activity taught them something they did not know before (Question 3 in the previous section).

> "I think it was something like **carbon sequestration**. And also how the thing that we were doing this weekend, **how you're presenting something, you have to also like try to present yourself as if you're part of the community**."
>
> --Participant L

Participant L's response about trying "to present yourself as if you're part of the community" is referring to the Climate Change Adaptation Plan activity when students had to develop an action plan to address task items set forth by the Yakama Nation to mitigate climate change effects in their community. Participant L expresses value for learning how to take different perspectives in order to enhance their climate change adaptation plan. Understanding who the stakeholders were for a particular task item was an important aspect of the Climate Change Adaptation Plan activity. Participant L gave another example of perspective taking when asked what Traditional Ecological Knowledge meant to them:

> "Like understanding how, I guess **in a community you're in a certain culture**, [you] see something and **how they interpret it in their own tradition, their own culture** and like **show them respect** by using their own language."
>
> --Participant L

Respect for others while realizing that "in a community you're in a certain culture" is an extremely important part of dialogic conversation. Participant L is giving examples of how information can be interpreted by different groups according to their own tradition and their own culture.

Authentic Activity

Authentic activities are those designed with the student (or learner) worldview as an important regulator for what is appropriate and for an outlook to what would be culturally relevant examples to enable understanding by the learner (Rodriguez, 1998; Cajete, 2000). Furthermore, authentic activities should align with the assessments and overall goals for understanding with

relation to the course topics (Wiggins & McTighe, 1998; McConnell et al., 2003). When participants/students are able to utilize their worldview in their own way to make sense of the presented material in a classroom environment, this can lead to much more impactful critical incidents, a characteristic that the sTc framework calls agency. By relating the discipline-based material to the everyday life of learners, we are able to transfer power to students since they can now use their knowledge in multiple contexts, not just the context of the classroom.

The activity that is strongly representative of both of these values is the Stream Table Activity (learning objectives for all modules are included in Appendix C). In this lab activity, students used stream tables to observe and record/draw their representations of a modern river depositional environment. Participants compared and contrasted the stream table environment with the definition and geomorphological characteristics presented in the textbook (Raven et al., 2015) as well as the features seen using Google Earth to look at the Yakima River earlier in the week.

The Stream Table Activity asked the students to reflect on what uses Western scientists and Indigenous communities (e.g. the nearby Yakama community) place on the earth materials from the river. An example of one of the questions used during the activity was: "What are the benefits and detriments to the river when considering the different ways that the river is used and sustained as a natural resource?". This activity directly ties a landscape that everyone in the Yakama and Yakima communities knows well, the Yakima River to the geoscience concepts being covered in the course. Many people from these local communities see the river everyday as part of their local commutes to school, work, and recreational sites. The stream table activity invited students to understand the perspectives of different stakeholders who depend on the river for their own motives. Also, this activity is scaffolding the cultural knowledge that community members have of the river as an informal meeting place for sociocultural events with the detailed information provided during the lab of how this geologic landscape was produced over geologic time.

The following quote from Participant E highlights how using the relevance of the river as an authentic activity enhanced their geoscience concept of an oxbow lake:

> "I feel like there was a lot of things that I learned that I didn't know before. Or at least in more depth. For example, the rivers, I mean, I know that **we can change the way the rivers, the path that it follows**, or we can make our own little ... **We can totally control**

> **the way the river moves**, in a certain way, but I never understood it **like those oxbows**, I think it was called, **I didn't know how they were formed. I just thought they were lakes**, or something, just there the whole time. I never really paid attention to, **they used to be part of the river, and eventually kind of broke in its own way. So, that was kind of cool, paid more close attention to that.** That was pretty cool."
>
> --Participant E

Participant E had noticed the oxbow lakes prior to their enrollment in the environmental science course. But it was only after they learned how they formed that they began to pay more attention to them. This is an excellent example of how authentic activities enhance the previous knowledge already held by learners. Participant E already had a concept of what the oxbow lake looks like as they passed by it on a daily basis, but the new geoscience information they gained about how oxbow lakes are formed helped increase their interest in them. They now pay "more close attention to that".

Metacognition

Metacognition is a practice embedded in self-reflection, but also in deep critique of knowledge holders (Rodriguez, 1998; Rodriguez & Berryman, 2008). Metacognition is often defined as "thinking about one's thinking", but this is insufficient for alignment with sTc because sTc focuses on the transformative aspect of metacognition. So, simply being aware of one's own thinking is just the first step: to fully provide agency (e.g. a transformative learning experience) for students, we had to make sure that learners not only considered what they were learning and how to demonstrate that learning for their instructor, but also to have students consider why they were learning the material they are presented with.

Additionally, metacognitive practice can also lead to questioning the motives of the instructor. This allows learners to be aware of how their learning holds (or does not hold) value for different stakeholders. People often do not consider our individual impacts on society but metacognitive practices allow us to consider these more abstract concepts. In this way participants are still able to communicate with each other, but individuals are given the choice(s) they deserve

to make fully informed decisions about the scientific, educational, and community practices they are being asked to take part in.

One of the activities that embodies the metacognition component of the sTc framework is the Geoscience Careers and Communication Styles activity (learning objectives for all modules are included in Appendix C). During this activity, participants were shown a graphic produced by the American Geosciences Institute (Houlton, 2015) showing the interrelatedness between geoscience careers and different sectors of society. After this introduction, participants were asked to participate in the E-colors activity (Equilibria, 2019) described earlier in the Geoscience Education Module section. Asking participants to think deeply about their communication style resulted in some interesting dynamics in the classroom during this activity. The following quote recounts one example of how these metacognitive exercises developed one participant's interpersonal communication skills:

> "Like that personality one, it was funny that ... The one with the colors or whatever, I was a red and a yellow. And it was funny because the only other person that had a red and a yellow, I remember **you asked us to compare why maybe some of us answered a certain way**, but she and I answered every single thing the same, and I was just kinda like, "Huh." And this is another person in the classroom that ... **I don't know if she didn't like me or we didn't like each other or something. It's just like the personalities, but it was, 'Uh, we're the same people, that's why!'** Do you know what I mean? That's why she stayed over there and I stayed over here. But I was just like ... **When we both looked at it we're like, 'Huh, maybe we have more in common than we thought originally' and I think that changed about her**. And so, since **after that, it seems cooler between me and her,** where it was just like the energy was kinda like "huh," but I think both of us realized like, "Oh, we're the same kind of person." **So I appreciated those type of activities that we did in class**."
>
> --Participant M

Participant M sees the value in the personality diversity indicator and the E-colors (Equilibria, 2019) activity because it helped resolve conflict between Participant M and another student. Prior to this activity, Participant M actively avoided the other student and it most likely would not have changed without a situation in which they had to communicate directly with each other. The E-colors activity was answered individually before participants were put in groups so there was no way to predict who would end up being paired with each other. There was tension between the two students but after thinking at a deeper level of *why* there might be tension allowed Participant M to change their communication behaviors with the other student and resolve some of that tension.

Reflexivity

Reflexivity works in tandem with metacognitive practices to enable learners to contextualize their understanding/learning not only with respect from themselves with society at large but also to how their individual actions can be considered as part of much larger movements, even at the global scale. By understanding the institutional structures that society operates within, we can effect change (i.e. create agency) more effectively. Reflexive thinking helps students transfer their newfound knowledge into multiple broader contexts, which then allows them to critique the institutional standards from multiple perspectives. This component of sTc is consistent with the value of autonomy, wherein learners are able to divest themselves of institutionalized thinking for a short time in order to make decisions more conscientiously and with a measure of skepticism.

The activity from the GEMs that exemplifies this facet of sTc is the Climate Change Adaptation Plan activity (learning objectives for all modules are included in Appendix C). This activity was described earlier in the "Geoscience Education Modules" section. The action plans the participants developed in response to the task items in the Climate Change Adaptation Plan (Yakama Nation, 2016) were all different, but all of the task items required groups of students to think about how the Yakama community's interests could be served while also considering the perspectives of non-Indigenous entities (e.g. scientists, local business owners, and local industries). The following quote exemplifies how Participant E used reflexive thinking to help start developing their action plan concerning task items related to the forest in the Yakama community:

> "At least for the part that I did, the forestry, I thought that it was, like I said, I thought it was good in the way that we talk about, the way that **I compared it with, I think it's in Brazil, or some place. I think it's Brazil, where they're thinking, 'Oh, well that's been done already.' Where you can see they've just cut down so many trees you could literally see the difference in one country and the country right next to it, big change, and loss of habitat too**…**I just thought it would be somewhat similar to that,** like, you can see the big changes, and why. **So it was similar in the way that you can still prevent that, by doing your part, planting your own trees, hoping, avoiding, because they're getting rid of the whole forest, because you don't just hurt the forest, you get rid of the plants, certain plants that are used for medicines and stuff like that.** So, obviously, you don't want to get rid of those. And also, I learned a lot of different things that you could do to help those parts, the forest floor's lacking, those types of plants are gone. You can plant more of them, just little things like that to make a change in the long run."
>
> --Participant E

Participant E used their previous knowledge of environmental concerns about forests in Brazil to connect their current project about forests in the Yakama community. Participant E sees the Brazil example as something to learn from and it informed their action plan to address their task item related to forests. The reflexivity component is exemplified because the student is contextualizing the Yakama Nation's concerns about the forest within a global lens, in which the Brazil example is an example of a situation where certain medicinal plants are now gone and efforts are now focused on restoration of the forest. Participant E explains that the Yakama Nation and other non-Indigenous stakeholders still have an opportunity to "prevent that, by doing your part".

Conclusions

The creation of place-based educational modules serves to bridge a gap between the currently disadvantaged educational experiences of underrepresented groups and the primary goal of our country and its educators to create an equitable learning environment for the diverse population our nation is built upon. While this project is focused on the needs and perspectives of Indigenous people, this approach is scalable to include other underrepresented groups and their cultural connections to geologic concepts. Additionally, the place-based geoscience educational modules could also be modified and/or constructed to meet standards set forth by the U.S. Government for primary and secondary education. Although the focus of this study is on geosciences, presentations about GeoConnections have been met with strong interest from educators and education researchers in other STEM disciplines that are struggling to engage the interest of a diverse group of learners. Thus, we hope that this work encourages continued exploration of place-based educational modules in a range of STEM disciplines, albeit in respectful and culturally sensitive approaches.

The GEMs described in this dissertation are examples of culturally relevant educational materials. Culturally relevant educational materials are a necessary component of culturally relevant pedagogy (CRP) (Ladson-Billings, 2009). CRP has been defined as using "cultural referents to impart knowledge, skills, and attitudes" (Ladson-Billings, 2009, as cited in Atwater et al., 2014). CRP also requires teacher beliefs to encompass the notion that all students are able to be successful within the science classroom (Brand, 2014). While these attributes of effective teaching directly benefit underrepresented students, it is our hope that sustained evaluation of culturally relevant educational materials (e.g. educational materials developed using sTc) will prove effective in increasing geoscience conceptual understandings of all students, including underrepresented students as well as those from dominant groups.

We anticipate that incorporation of Indigenous cultural values into educational materials, (e.g. GeoConnections GEMs) will increase Indigenous students' understanding of the relevance of the geosciences to their communities and will also increase their interest in geoscience careers. Along with this increased engagement from students with culturally relevant science there should also be an increase in the critical thinking, metacognitive, and reflexive thinking skills of these students. Prowess in both arenas of Indigenous knowledge and Western would propel Indigenous students to be successful in academia as well as other careers more closely aligned with their

cultural values (Brayboy, 2008). A long-term goal of GeoConnections is to increase the number of Indigenous students choosing to study and pursue careers in the geosciences. Additionally, the primary researcher, Mr. Reano, sees the proposed engagement of a network (undergraduate students, graduate students, and faculty) of scientists working together for improved educational outcomes as a bridge between discipline-based researchers, educational researchers, as well as the next generation of scientists.

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USING INDIGENOUS RESEARCH FRAMEWORKS IN THE MULTIPLE CONTEXTS OF RESEARCH, TEACHING, MENTORING, AND LEADING

Introduction

Indigenous research frameworks (IRFs) are quickly becoming the preferred approach to conducting academic research that impacts Indigenous communities. However, much of the research being implemented in these communities does not involve direct collaboration with Indigenous community knowledge holders, does not authentically engage Indigenous Knowledge (IK) held within Indigenous communities, undervalues long-standing traditional systems of knowledge perpetuation, and does not incorporate long-term benefits to the community (David-Chavez & Gavin, 2018). Some of the tension in these relationships lie within the fact that while many researchers cite examples of IRFs and the research projects in which they are used, many non-Indigenous researchers do not have adept experience working directly with Indigenous communities. In order to reflexively understand this phenomenon from my current perspective (a relatively young Acoma geologist straddling the boundaries between Indun Country, science, and education), I am analyzing practical examples of my own research, teaching, mentoring, and managing practices. These examples evolved from an honest approach to materializing Indigenous research frameworks and the theoretical values they uphold into tangible interventions I have led during the past several years of entrenchment within higher education institutions. I have also chosen to use autoethnography (Hughes & Pennington, 2017) as a way to centralize my voice both as a member of the Indigenous community and as a researcher of Western modern science (WMS).

Indigenous research methodologies can be very restrictive in the sense that the practitioners (both Indigenous and non-Indigenous) who adopt these methods must hold themselves to a higher standard (Smith, 1999). Sometimes this is due to discipline-based educators challenging the validity of their results from WMS perspectives. In addition, however, Indigenous ontological and epistemological approaches to research and education require a nuanced understanding of how intercultural exchanges of information should be handled (Brayboy & Castagno, 2008; Smith et al., 2016). While some educators and researchers are able to do this effortlessly (Ladson-Billings, 2009), more often Indigenous scholars and Indigenous communities share stories about how their cultural values have been disrupted by individuals who refuse to discern their appropriate

relationships within Indigenous communities, especially as they conduct research (Jacob, 2013; David-Chavez & Gavin, 2018). This politicized stance, from the very start of a research project, regarding the underlying purposes, motivations, and utility of the research and the researcher is often dismissed within WMS research designs. In effect, many WMS researchers are unwilling to invest the time (e.g. time spent away from other research projects, time necessary to build cultural competence, preference for the siren call of a ticking tenure clock) necessary to authentically engage with Indigenous communities. It is also an unusual proposition to WMS researchers be asked to proffer academic positionality (e.g. perception of research utilizing IRFs as less than scholarly, offering co-authorship to Indigenous knowledge holders, citing Indigenous Knowledge) (David-Chavez & Gavin, 2018). Other WMS researchers have competing political interests which may preclude them from participating in research projects founded on Indigenous research frameworks. Collectively these barriers have historically led to a decreased number of WMS researchers who are authentically able to utilize IRFs within their research practices.

Introduction to Darryl Reano

The following section is a long excerpt from the self-interview. It is meant to serve as a way for readers to understand my relatively recent introduction to Indigenous research frameworks and how I began to use them in conjunction with geology/geoscience.

"I had never really heard about Indigenous research frameworks… until the beginning of my PhD time, which started in Fall 2014. The undergrad that I went to the classes were pretty much straightforward typical geology classes, lots of field components. In a way, geology is almost more focused on experiential learning rather than theoretical learning. You're out in the field a lot, you're looking at stuff, you're trying to describe minerals that you can look at and actually point out and see rather than ideas that are abstract like math where it's just numbers.

When I came to graduate school, it was pretty similar. It was a different kind of thinking though, because I was exposed to geology literature. I started getting into that where it was like, this is how you lay out a research problem, this is how you go about answering it and also connecting it to the broader literature. I remember one of the first classes that I took was this mixed-methods in engineering education class. It was a relatively new class, I think maybe it was the second time or the third time it was taught. It was co-taught by a couple of people from the

engineering faculty. But it was really interesting for me because they explained how quantitative research is much more useful for explaining "what"… whereas qualitative research can help you understand "why" certain things were happening. I thought that was really useful.

That class was also the first time I started hearing about theoretical frameworks. That was when I started realizing that "OH!", all the science that I have been doing has a theoretical framework, but it's never really mentioned and it's this assumption that everyone is on the same page with that. It was interesting to find out that there are other frameworks… For me, the interesting part has always been the connection between science and social science. The geology work that I've done, thinking about the human components, it was interesting because throughout my academic career or whatever, the people [researchers] I met would always talk about that. The implications of their research, the broader impacts, "how is this useful?", "why should people care about it?", but it [the broader impact of research] was always kind of off to the side.

I started hearing about social justice frameworks that were focused on equity and looking at that-- not just at the end of a research project but from the very beginning! How do you come up with a research question, talking to communities, and [maintaining] long-term accountability to communities. All of that was powerful for me because I didn't think that was something scientists or researchers in general really talked about or cared about. I know people care about it on a personal level a lot of times but they don't typically bring it into their work that I've seen, especially in geology. That's not really a thing at all.

It was within that first couple of years that I found out about Indigenous research frameworks that really got me thinking more broadly about the Indigenous experience in general because I was realizing there's all these people writing about this same topic but they're coming at it from different angles and I don't necessarily agree completely with any of them but there are definitely components of all of them that I agreed with and so that was really fascinating for me too because that idea of "Oh!, they're trying to generalize something but it's not really generalizable". They keep saying that too, in their own work too, that it's not easy to talk about it in the words of English.

I think that's where my interest starting peaking was like, is there a way to frame this in a more generalizable term because I feel like that's something that Western scientists-- that's something they look for. I was thinking if you could do that with the [Indigenous] framework--

explain the framework in a way that they could understand-- that would make it more appealing to them.

The way that I started thinking about these Indigenous research frameworks is… you have an audience. You choose who you're writing for in terms of an audience. In a lot of these Indigenous research frameworks, they're writing for other Indigenous communities. I think that in itself can stand on its own, but my goal is not just to put forth another Indigenous research framework. One of my goals is show Western scientists why they should value Indigenous knowledge and Indigenous research frameworks because I think that getting buy-in from the larger broader [academic] community that doesn't really know what it is and they haven't really seen any examples of it in practice, especially in my discipline. A lot of the examples come from biology like traditional medicinal plants. Those sorts of Traditional Knowledge and that's really respected…it's very direct.

I think Indigenous Knowledge about geology is much more ... There's these long-term geological changes that you can't really describe in that kind of detail. It doesn't have a single use. It's just long-term continual process that people are describing and so they use metaphor a lot and it's not really something that you can go out and test. Even regular geology, geologists understand that, that we can't cause earthquakes to happen, we can't wait around 400,000 years to make sure our Milankovitch cycles are on time or whatever. They have this understanding that some things aren't testable.

What I'm trying to do then is show another example of ways that we can glean geological knowledge from the global community but I think that Western science has a lot of growing to do in terms of how they treat people and how they attack issues. A lot of times their values are similar to Indigenous values in the sense like people want to be happy, people want to be somewhat comfortable, all these things but it's more about ***how*** *they go about doing that. Scientists just coming into [Indigenous] communities, doing research, leaving, even maybe devastating the community, but they [the western researchers] learned something. I don't think that's a very good approach. If you're thinking about the entire community as a whole rather than just a select few groups within the community that you're trying to benefit the most. I have reservations about that part.*

Giving access to western scientists to Indigenous knowledge I think is really contentious among Indigenous scholars and even just all Indigenous communities-- there's disagreement about

what that level of access should be, whether or not people should share their knowledge, their stories outside of their local community. Even from Native community to other Native communities like where I'm from [Acoma Pueblo and Kewa Pueblo], Pueblos are very protective of that information. What I do, is I try to focus on just the geological aspects, nothing more than that. Things that you actually just see walking around and censoring some of the more sensitive information and allowing the community to be the arbiters of that. Papers that I write, I'll put down some things and then I'll send it back to them to have them look at it to make sure that if there's something they don't like or they don't want in there, they can take it out. That way, it's not just my own personal opinion of what should and shouldn't be, but it's actually a group of people.

I started hearing about these other people in Canada that are setting up these Indigenous IRBs essentially where they go through gatekeepers within the community anytime research is being done with or about these communities. I think that's one thing to look for in the future for Indigenous communities in the United States. I think you'll see more of that as more Indigenous scholars are becoming aware of all the different processes we have to go through for other communities, so why should we not have those same protections at home?

When I started using IRFs, there was this weird expectation that Indigenous Knowledge would enhance Western scientific knowledge in similar ways to like I mentioned about biology where like, we're gonna discover this new chemical, this new chemical that's never been described before. It would the same thing as this Native community, they showed us this layer of rock that we've never seen before, we never saw it mapped anywhere and it gives great insight into the evolution of this geologic basin. I don't see that as a primary benefit [of using IRFs] because a lot of communities geology-wise have already been infiltrated. People went across my Reservation, mapped the whole thing, there's a map of it, people know what rocks are there. They already have a sense of what's there, and so any information that we bring back is usually seen as ancillary. It's just sort of "Oh, we knew the big story, you're just adding this small piece of information that maybe we missed, maybe we didn't. We would have found it out if we were still working on it". In that sense, people devalue Indigenous knowledge.

What I think Indigenous research frameworks bring that Indigenous Knowledge by itself doesn't bring is this relational aspect. How interpersonal relationships, how people communicate with each other, there's more respectful attitudes among people when you're considering their opinions, their values, their cultural beliefs. When you're forced to empathize in that way, you're

getting past your own ideas about how things should be and opening yourself up to new ideas. I think that's really important for growing the higher education community because that's a lot of what we do-- is opening ourselves to new ideas and finding new ways to solve problems. The relational aspect, people relating to people, people communicating better, people feeling respected because I think a lot of things that I see happening in geology or the issues, the diversity and inclusion issues I see are related to sexism, they're related to ableism. There's just this sense of exclusion for a lot of people [in academia].

What IRFs would bring is a greater diversity of students that feel welcome in that [academic] environment so that we can have people from different backgrounds learning about the same material together. Their unique life experiences will help flavor some of the research that they do and how we approach different research questions and even which research questions we decide to approach. Just like I was saying about geology, there's not too many people that are interested in what Indigenous communities' connection to geology even is. Doing that is for the benefit of indigenous communities but the things that western science can learn from that is how to treat people well. That still is not trying to change their goal either. They're just trying to get information, they're learning knowledge, but again, it comes back to ***how*** *they do it. It's* ***how they treat people****,* ***how they treat communities, how they treat the environment****, as they're approaching these different research questions."*

Darryl Reano Self-Interview, 2019, brackets and bolding added post-interview

Theoretical Perspective & Methodology

The theoretical perspective I am using is that of Tribal Critical Race Theory (Brayboy, 2005). This framework centralizes Indigenous perspectives and demands context in situations where Indigenous communities will be involved in research. This is important because of the history of negative interactions (i.e. colonization, racism, loss of data sovereignty collected through WMS research) between many Indigenous communities and outsiders to those communities (Smith, 1999).

Autoethnography was chosen for its usefulness in valuing alternative perspectives that seem to run counter to Western modern science (WMS) positivism as well as a way to engage in critical, reflexive thinking about how practical knowledge gained from lived experiences can enhance understanding of scientist's positionality during the scientific process (Tomaselli et al.,

2008; Hughes & Pennington, 2017; Masta, 2018). This is useful because it allows a transformative approach to begin developing from a comprehensive understanding of social dynamics (e.g. a researcher's relationship to participants in a research project) and traditional WMS empirical data (e.g. results/analysis from a research project). Non-qualitative researchers often mistake autoethnography for storytelling without a connection to theory or research. Hughes & Pennington (2017) offer three distinct patterns of autoethnography that enable researchers to legitimate their research and offer new perspectives (e.g. Indigenous) that will transform the disciplines of WMS. The approach used for this article is to claim links to existing qualitative constructs (Hughes & Pennington, 2017) which requires careful attention to fairness, ontological authenticity, catalytic authenticity, educative authenticity, tactical authenticity, methodological rigor, and aesthetic rigor. These terms and their contexts within this autoethnography are discussed in the following paragraphs.

Fairness in this context is dependent on whether different social constructions of reality are explicitly identified during the writing process. I have spent many years within the WMS academic system. Separated from my family with only a few visits each year for at least half of that time. My familiarity with WMS and my identity as a scientist expose me as a representative of WMS to my home communities. It was not until I was exposed to the research of other Indigenous scholars (Brayboy, 2005; Wilson, 2008; Masta, 2013) that I was able to understand why I was constantly reinterpreting the knowledge I was exposed to in the WMS classroom into a more personal, culturally congruent (i.e. Acoma) understanding of the WMS concepts (Gay, 2010). In this way, I have stakes in both the promotion of Indigenous Knowledge as a valid source of information as well as the continuation of WMS efforts to mitigate natural disaster and enhance the overall health of the global Indigenous community.

Ontological authority is related to a critical self-reflection that examines whether a researcher's values and social constructions of reality are improved by virtue of having more evidence-based information (Hughes & Pennington, 2017). This requires a deep understanding and transparency of my own positionality. My positionality is necessarily one focused on inclusion because of the marginalization I have experienced.

Catalytic authenticity is the mediation of new, transformative ways of thinking that are now apparent after self-evaluation (Hughes & Pennington, 2017). These could be new senses of understanding of relationships between positionality and theory or a desire for change to pedagogy

currently being used. This liminal space is created now to form a foundation upon which transformative action (i.e. tactical authenticity) can be produced.

Educative authenticity is understood to represent the degree to which a sense of appreciation for entities outside of one's own affinity groups are enhanced and their social constructions are respected. This is a reciprocal process in that both the researcher (e.g. autoethnographer) and the audience (e.g. persons reading an autoethnography) are invited to reflexively integrate their understandings of the social constructions and rectify those with each other. This is a necessary component because although many autoethnographers are writing for a specific audience, the scholarship is incorporated into the larger academic inventory of writing. Whether we choose to write for them or not, people beyond our intended audience will be reading our works.

Tactical authenticity is the mobilization of the transformative practices recognized within catalytic authenticity (Hughes & Pennington, 2017). This ensures that theory is not the ultimate end of the scholarship done within autoethnography. It is important that we not only explicitly recognize theoretical constructs that are evidenced by our own experiences but that this knowledge is transformed into something useful that can benefit future generations of scholars, researchers, and communities.

Methodological rigor refers to the standards being used for interpretive and constructivist inquiry in contrast to the standards of WMS which include validity, reliability, and generalizability (Brayboy & Castagno, 2008; Smith et al, 2016; Hughes & Pennington, 2017). In the context of this autoethnography, the purpose of this research is not to generalize my experience or to validate my singular experience as something that all underrepresented students will face (Smith et al., 2016). Rather, the purpose of this autoethnography is to reveal WMS institutional values that are supportive of the use of IRFs to enhance higher education (Brayboy & Castagno, 2008). The methodological rigor for this work is thus more concerned with **why** the use of IRFs is successful in these particular instances as opposed to finding some universal characteristic that implies that IRFs are needed.

Aesthetic rigor is the level of acquiescence to accepted standards for literary quality (Hughes & Pennington, 2017). For autoethnography, this is a useful criterion to be mindful of because personal experiences are shared throughout, but without adequate backup from the current

literature of an academic discipline there would be different utilizations of the work besides induction into the literary canon of academia.

Together these criteria form a base foundation upon which the personal experiences of researchers can be integrated to form a more holistic, contextualized perspective of the research experience. In my context the use of autoethnography has led to research that yearns to answer the questions of why WMS research is practiced a certain way, how Indigenous ways of knowing survive within WMS institutions of higher education, and also the pragmatic applicability of Indigenous Knowledge within WMS traditional pedagogy. To this end, the theoretical perspective I am using is equally important as the research method.

In order to expand my thoughts into a reflexive exercise that would allow me to connect my personal experiences to broader bodies of literature in science education, critical theory, and Indigenous knowledge, I used a self-interview technique (Hughes & Pennington, 2017). Self-interview and other reflexive techniques are especially important within Indigenous contexts because they allow the explicit recognition of positionality's influence on the research process (Tomaselli et al., 2008). I developed a set of seven questions related to my experiences teaching, mentoring, and leading student organizations while using Indigenous research frameworks to guide my styles of pedagogy and communication. Another Indigenous qualitative researcher administered the self-interview and was allowed to exert some influence on the wording and order that the questions were asked. Additionally, the external interviewer included follow-up questions that helped broaden my understanding of the connections between the different contexts in which I have used IRFs. The interview lasted about ninety minutes and included a debriefing session after the interview was completed to reestablish regular communication between the external interviewer and myself. The self-interview data is used primarily to preface the multiple contexts in which I have used IRFs and is also included in the discussion section in order to clarify different relationships among my experiences using IRFs.

Indigenous Research Frameworks

In my own research, I also rely heavily upon the work of Wilson (2008) because he has usefully juxtaposed Western scientific research principles (i.e. axiology, epistemology, etc.) with those of IRFs. These two ways of knowing can be quite different but, depending on how they are

used, they also can have very similar goals (e.g. enhanced learning of students, long-term sustainability).

Indigenous research frameworks developed out of a need for Indigenous scholars to find ways of doing science that did not depend on them betraying their cultural values (Wilson, 2008; Masta, 2018). For many Indigenous communities these cultural values are sustained through daily practice and this is true even after they have become scientists who are constantly in communication with Western academia.

Indigenous knowledge is widely held as place-based knowledge built upon the needs of Indigenous communities that have maintained their status for hundreds of years (Cajete, 1994; Smith, 1999, Snively & Corsiglia, 2001; Hikuroa et al., 2011; David-Chavez & Gavin, 2018; Garcia, 2018). Indigenous knowledge is thus immersed within the cultural and spiritual values of the Indigenous community from which it is derived. Often, Indigenous knowledge has utility and performs a necessary function for the perpetuation of an Indigenous knowledge system.

Shared Values of Indigenous Research Frameworks

While there are many examples of IRFs (Brayboy, 2005; Grande, 2008; Wilson, 2008; Kovach, 2014; Masta, 2018) with distinct characteristics, they do hold commonality as well:

- A **holistic** approach that emphasizes the interrelatedness between Native communities, their local environment (e.g. place-based education), their political agendas (e.g. multiculturalism, social justice, diversity efforts), as well as outsider perspectives of Indigenous knowledge and its uses (e.g. efforts to integrate IK and WMS) (Cajete, 2000; Brayboy & Castagno, 2008; TallBear, 2015; Smith et al., 2016).

- **Relationality** (relationships between both human beings and human beings and their environment) as a core tenet for how Indigenous Knowledge is produced and legitimated outside of the academy (Cajete, 1994; TallBear, 2015; Cajete, 2008; Smith et al., 2016). This is, in effect, the incorporation of an Indigenous sociocultural frame of reference or way of knowing (Cajete, 2000).

- Acknowledgement and **centralization of Indigenous perspectives** of stakeholders and conductors of research, who are Impacting indigenous communities, into all aspects of the research process (Cajete, 2000; Brayboy, 2005; Zywicki, 2013; David-Chavez & Gavin, 2018; Masta, 2018)

- Continual evaluation (e.g. formative feedback) of how the research being conducted **serves the interest(s) of Indigenous communities**, including the quest for sovereignty and other sociopolitical interests found within Indigenous communities (Smith et al, 2016; David-Chavez & Gavin, 2018; Masta, 2018).

- Acknowledgement of **multiple ways of knowing** (multilogicality), which allows "science" to be critiqued as a culturally-grounded construct and also allows Indigenous knowledge to be broadly legitimated as well as critiqued (Smith, 1999; Cajete, 2000; Brayboy & Castagno, 2008).

- Acknowledgment of the importance of a "**spirituality component**" to Indigenous research. This facet is primarily a reflection of how many Indigenous communities incorporate their spiritual behaviors into their everyday lives (Cajete, 2000; Brayboy, 2005; Cajete, 2008; Smith et al., 2016). It is assuredly different depending on your community and family (Brayboy & Castagno, 2008; Cajete, 2008; Masta, 2018).

These shared values of IRFs are important because they show how Indigenous communities "think alike" (Hikuroa et al., 2011; David-Chavez & Gavin, 2018) and why they are able to come to a base consensus of how inter-communications should be emplaced even with stark differences between Indigenous communities.

Multilogicality of Indigenous Research Frameworks

While there are shared values among IRFs, there are also values that Indigenous scholars and WMS researchers contend with (Smith et al, 2016). Kincheloe & Steinberg (2014) argue for the addition of a component within Indigenous approaches to communicate with outsiders (primarily non-Indigenous) to Indigenous communities. They argue that having political allies

outside of the local, Indigenous communities allows for change to happen at a broader scale. This struck a chord for me because in my own specific culture, Acoma Pueblo culture, there is an unspoken sense of distrust for all outsiders, but most especially when they are proposing Western scientific research that could impact our community (Cajete, 2008). This places a burden on Indigenous researchers to embrace the sharing of Indigenous Knowledge (IK) outside of the Indigenous community. While some Indigenous communities are open to sharing this type of information (Morton & Gawboy, 2000; Wall & Masayesva, 2004), other Indigenous cultures are less inclined to share Indigenous Knowledge, even in the face of detrimental aftereffects. This solidarity at Acoma Pueblo is not intended to ostracize outsiders to the community, but is intended to create a unique bond between Acoma Pueblo community members in celebration of our shared worldview and values (Minge, 1991; Cajete, 2000).

Additionally, some Indigenous community members might view this aspect of a "generalized" Indigenous approach to research as having to justify their traditional epistemologies to outsiders (Wilson, 2008) when they might much prefer to maintain their epistemological foundations within (and ONLY within) their local community. The Indigenous research frameworks I use structure the framework in a way that allows for these divergent viewpoints to be recognized, accepted, and respected. I do not see a way to avoid essentialism in an inscribed Indigenous approach to incorporating Indigenous knowledge into research and education. However, Indigenous knowledge is dynamic and open to contemporary development. Kincheloe & Steinberg (2014) acknowledge the dynamic relationship between Indigenous worldviews and those who stand outside of the global Indigenous community but fail to adequately incorporate this fluidity (Kincheloe & Steinberg, 2014) into their paradigm. Indigenous scholars have voiced a concern that these *fluid, dynamic relationships are not easily captured in an articulated indigenous approach to incorporating indigenous knowledge* into research and education (Cajete, 2008; Masta, 2018).

Another contested aspect of IRFs involve the way that researchers satisfy the component of "serving the interests of Indigenous people and their communities". This is statements can mislead non-Indigenous people (e.g. researchers) into believing that *all* Indigenous communities, and individuals, align preternaturally in terms of their political interests, societal needs, and Indigenous worldviews. As mentioned previously, Indigenous communities can have drastically different approaches to interacting with non-Indigenous entities, especially when it comes to

communicating sensitive cultural information that can be misused. This creates a contradiction because some researchers (Grande, 2008; Kincheloe & Steinberg, 2008; Kovach, 2014) mention avoidance and/or denial of essentialism within their perspective of IRFs due to its detrimental effects on Indigenous communities and individuals. However, *articulating* an Indigenous approach to incorporating Indigenous knowledge requires, at the very least, an essentialized wording (that erases specific histories of uncountable Indigenous communities) while creating an inclusive statement that "works" for all Indigenous communities.

My own approach has been to *not try and include all Indigenous communities into a single framework*. Instead, in most of my work, I have chosen to combine IRFs with socioTransformative constructivism (sTc) which allows a generalized approach (sTc) to research and teaching that is then contextualized through the use of IRFs for specific Indigenous communities. There should be a purpose in grouping Indigenous communities together and this could be based on similar political goals, similar environmental contexts, similar historical (albeit separate) contexts, etc. My purpose in this manuscript is to develop an understanding of how an Indigenous research framework can be wielded in faculty activities beyond research. I would agree that searching for that "perfect word or concept" that transcends (and yet captures) specific, cultural contexts of Indigenous worldviews, values, and/or goals, is an outdated approach to understanding commonalities found within the global community, including Indigenous and non-Indigenous worldviews (Brayboy, 2005).

A third criticism of IRFs is related to the aspect of spirituality and its consideration as a necessary component of Indigenous approaches to research and education. I cannot disregard the role that spirituality holds within Indigenous worldviews, but I practice prudence when trying to accurately describe what is (and what is not) deemed "spiritual". Grande (2000) writes that Indigenous approaches should have "Earth as its spiritual center". Grande does not elaborate on this statement. Other Indigenous researchers (Cajete, 2008) use generalized wording that is not specific to any particular Indigenous community, but is supposed to reflect shared insights from many different Indigenous communities. Acknowledging spirituality in educational contexts is a direct epistemological challenge to non-Indigenous researchers in the academy who would prefer to see spirituality maintain its sociocultural role outside of academia. While I support the notion that Indigenous spirituality need not be validated by non-Indigenous individuals/communities, I still grapple with my identities as an Indigenous person, who sees great value in acknowledging

phenomena beyond what WMS can explain, and a researcher trained at a major university, who denies the relevancy of spirituality to research. If spirituality is explicitly named within an Indigenous research framework, that could require that the Indigenous community involved in research be open to discussions of Indigenous spirituality. These discussions can quickly become problematic if Indigenous perspectives are not at the forefront in a respected position. My own lived experience tells me that *there is no direct consensus of which aspects of indigenous spirituality are open to critique by non-Indigenous parties*.

Indigenous research frameworks within multiple contexts

The following sections of this manuscript will be used to highlight several experiences from my time as a graduate student working on my dissertation. The teaching components were culled from the various teaching experiences I held as a graduate student, including teaching assistantships for introductory geology courses and co-teaching an introductory environmental science course. The mentoring section is founded on my experiences mentoring both Indigenous and non-Indigenous students in both formal and informal settings. The context of "leading" refers to my time spent as President of the Purdue American Indian Science and Engineering Society (Purdue-AISES). All of these contexts were happening concurrently and at a time when IRFs were beginning to become a major facet of my professional disposition. Each section will begin with a brief explanation of the context of the experiences, followed by an excerpt from the self-interview that describes the relevancy of the context (i.e. mentoring, teaching, leading), and will be completed with an analysis of the connections between the multiple contexts and the shared values of IRFs (e.g. holism, relationality, spirituality) described earlier in this text.

Using IRFs for Teaching

I have been a teaching assistant for 8 years teaching both introductory level geology courses (mostly non-majors) and upper-level courses for geoscience majors. I have also had the privilege of teaching undergraduate students through "GeoConnections". GeoConnections is an NSF-funded project for which I wrote the bulk of the proposal. This project was focused on creating culturally relevant geoscience education modules. These modules were developed using Indigenous research frameworks and so aspects of IRFs have been integrated into the development of each of these modules. During the implementation of these three modules (a total of 15 class

hours) I was also present on a campus in the state of Washington. As mentioned previously, using IRFs for teaching requires a holistic approach. For me, this means that teaching does not stop immediately when class is over. There were numerous times in both sets of experiences when students approached me by themselves as I was walking around campus to converse about the scientific topics we were covering in class. These interactions were not necessarily instructive (in terms of Western scientific content) but were usually about contextualization—allowing students to voice the connections between the Western scientific content and their daily lives within their various communities, academic and otherwise.

"It's not easy. It takes time to develop relationships with people that aren't directly benefiting you [or from you]. From what I've seen, the expectations for say a teaching assistant in our department would be: you have to give this lecture, they'll have an assignment, answer any questions that they have about their assignment, and then after they're done grade it, get it done, enter it into the grade book, and then next week do the same thing. That's the extent of the relationship that's expected between a teaching assistant and a student. But what I've seen is that you'll have different levels of engagement from different students from the very start of the class. Where some people are interested, they're happy to be there, they want to learn the material. Some people maybe already know the material, and they're just kind of getting through the class. They don't need help but they don't really want to be there anyway. Then you'll have the other students that are just completely disconnected.

I think that traditional approach [to teaching] fosters this sense of sink or swim. "If you don't want to be here, you're gonna get an F. If you're not trying, I'm not going to help you. You're gonna not pass." If you use Indigenous research frameworks in that same space, it's much more focused on the students, and it's a reciprocal relationship. I'm not there just to give off knowledge and spew it forth and have people understand it. I see it as this relational aspect of IRFs—it's like asking me to find out what the student's perspective is and figure out their level of engagement, and then if they're not engaged, finding different ways to engage them. Which, for me, is often talking to them about things beyond the science, beyond the concepts we're learning in that class because a lot of them are from different majors besides geoscience and so they're trained within their departments to be thinking towards their own careers. A lot of times it's say, computer science or business construction management. I think finding ways to connect the geoscience concepts to

their goals and to their values is really important for increasing their engagement. I think IRFs are a natural way to do that. It just ***creates a better communication flow*** *between the teacher and the student.*

Like I said, it doesn't happen immediately. In your first class, you're like "Let's just open up the floor and everyone tell me how you feel about geology". That doesn't really work because there's a level of ***trust that has to be developed first****. That requires vulnerability on both parties' accounts, so you're not gonna immediately have that sense of trust from the beginning of a relationship. That's something we've learned about working with Indigenous communities and why these Indigenous research frameworks include that as a component is because we've seen this over and over again… if you're not considering the needs and perspectives of the people you're working with, then the communication just is not as good as it could be.*

Once I started learning about Indigenous research frameworks, I felt like wow, this is a really powerful tool. I have the power to use it, why would I not be using it? Because it seemed like doing a disservice to the students I was working with at the time. I'm at Purdue, so they're not Indigenous students, they're predominately White. There might be a few underrepresented students, like maybe some international students or a few other Hispanic students, African-American students too. I don't think I've ever had an Indigenous student at Purdue.

One of the first things that I wanted to talk to the students about was transparency. Then I went on to explain, you should really be considering who I am as a teacher. Why am I teaching you this material? Why are we sharing these ideas with you? What are you going to use this knowledge for? Also, about the textbooks, it was like, why have they arranged the information in this way? What underlying goals do they have for you after having read this book? Yeah, you'll learn geology, but then what? What's the next step? That was really eye-opening for a lot of the students. They were really fascinated by this idea that they were being molded without realizing it. But I was being explicit about it. Of course, the first few questions I got back were like, "What about you?" "You're teaching this class, what's your role in all of this?" I'm like, "Exactly, that's what I'm saying is: Ask me. Ask me and we'll talk about it. Yeah, I'm here as a graduate student. I didn't choose to teach this class, I was assigned to this class. Yeah, like I said, you can go to an oil and gas job if you want to after this or you could be doing something else and if that's what you're more interested in, I can help you in that aspect too. I just want to let you that there's options, so that you don't get to the end of your program and then you feel like there's only one

option that you've been prepared for." That was really interesting. That was one aspect, this transparency aspect of who I am, what the knowledge is for, what are we training them for.

I was telling the students from my older perspective that the people in this classroom, you're going to see [them] in the future. Maybe not in the couple of years right after you graduate but years from now you'll be hearing about people doing different things and you'll maybe want to have that connection with them, so make those connections now to start building your relationships with each other now. That will benefit you later on, even if it's just to have another perspective of somebody that went through the same experience as you in undergrad. I set up a GroupMe for the students to be able to ask me questions anytime and so they had 24/7 access to ask me stuff and it also fostered communication between them. They would study together. They would pose different homework questions and answer amongst themselves. It wasn't just ask Darryl a question and get an answer. It was actually creating a community among them. After that class was over they took a few more classes maybe together but they stayed a strong group. They were still friends long after and our GroupMe is still active years later. It's true. They've all gone off to different things but we still connect back to each other. Many of them told me that they really appreciated that I asked them to talk to each other and really just formed those relationships as a natural part of the course."

Darryl Reano Self-Interview, 2019, brackets and bolding added post-interview

Holistic

GeoConnections, implemented at a small private university in the state of Washington, reflected the holistic nature of IRFs through the different relationships we highlighted during the development of course materials between the Yakama people and local geologic features such as the Yakima River and the Columbia River basalts. In the climate change report, the Yakama people distinctly identify cultural resources as impacted by climate change. This is a disruption to the WMS science idea that only physical natural resources (ones that can be economized/sold for profit) are worthy of inventory or engagement (Brayboy, 2005; Smith, 1999). Another inclusive/holistic aspect was how we structured the stakeholders in the modules. Stakeholders we included in our activity were local business owners, Indigenous communities, Yakama First Foods, scientists, local community members, and students. Therefore, even though we privileged Indigenous perspectives, this did not mean that we excluded the dominant perspective from the

discussion. Additionally, students were encouraged to continually add new stakeholders as the discussion progressed and new interests and needs of unmentioned stakeholders became evident.

The lab environment also included holistic aspects evidenced by the fact that we sometimes had children with us in the classroom during lab times. In this particular small university setting, careful attention is paid to the various barriers that may prevent students from wholly participating in class activities and assignments. The children present during lab did not disrupt the lab activities we were doing, but instead allowed all of us to have an intergenerational educational experience. During this lab period, parents were able to expose their children to current practices of college students and model the behavior of a successful student. This experiential aspect of perpetuating Indigenous knowledge is invaluable. In this case we were also perpetuating Western modern scientific knowledge in the same space, which showed the younger participants that these two knowledge systems are not incompatible in practice.

Indigenous community members were also invited into the classroom in an effort to expose the class to unfiltered Indigenous perspectives. In actuality, the community members who came were older students or had graduated already but maintained a connection with the Indigenous students on campus, the instructor of the course, as well as other faculty at the university where GeoConnections was implemented. For much of this part of the modules, I did not pretend to have extended knowledge about the First Foods of the Yakama people, instead I deferred to those community members who had much greater expertise than I do as a visitor to the area and outsider to the Yakama culture.

Relational

In GeoConnections we implemented an activity involving E-Colors, "a personality diversity indicator" (Equilibria, 2019), that has been used in training new employees at major energy corporations. This activity was designed to alert individuals to intercommunication skills that may need to be developed in addition to potentially "inherent" communication styles. In industry settings, lack of development of these skills can pose significant threats. For our purposes, we were more interested in having students develop a reflexive mindset (Rodriguez, 1998) that would allow them to interpret their individual educational experiences during the GeoConnections project within a broader context (e.g. within Toppenish county, Washington State, the United States, the global community). However, to begin this pattern of reflexive thinking we asked

students to consider their relationships with other people in the classroom as well as people within their communities. This was a preemptive approach to having the students begin planning a community-based action project that would allow them to directly address climate change tasks dictated by the Yakama climate action report (Yakama Nation, 2016).

Centralization of Indigenous Perspectives

In GeoConnections, as part of the "Yakima River Module", we also emphasized the First Foods of the Yakama nation as having a voice and respected position within the ecosystem. This emphasis is repeatedly mentioned throughout the Climate Change Adaptation Plan (Yakama Nation, 2016) we used for this activity. For the Yakima River Module, this meant that the survival and sustainability of First Foods for future generations (Yakama Nation, 2016) was of prime importance as we considered Indigenous perspectives, specifically those of the Confederated Bands and Tribes of the Yakama Nation. This was especially important because this course took place on the lands of the Confederated Bands and Tribes of the Yakama Nation. This Yakima River Module is an example of developing relationality between human and non-human entities within the Yakama ecological landscape. By putting the needs of non-humans (e.g. First Foods) as paramount, we were able to discuss sustainable approaches that would incorporate multiple perspectives (i.e. Indigenous and non-Indigenous) when trying to mitigate climate change impacts (Brierley et al., 2018; Tallbear, 2015).

Serving Indigenous community interests

In the "Policy and Communication Module" for GeoConnections, we addressed climate change concerns coming directly from the Yakama Confederated Bands and Tribes of the Yakama Nation (Yakama Nation, 2016). The major portion of lab time during this module focused on the development of an action plan to address task items set forth in the Climate Change Adaptation Plan (Yakama Nation, 2016). This included the identification of key local community stakeholders through a power-mapping exercise developed from materials used by the Earth Science Women's Network (Glessmer et al., 2015). We asked the students to not stop at finding names of important people in the community they thought should be involved, but we also asked them to find direct contact information to make it more apparent that the next step would be to actually contact the people who were in positions of power in order to begin a collaboration. Students were then invited

to implement their proposals with the instructors of the course explicitly offering to help materialize the action plans of the students. However, students, at the end of the semester, were reluctant to pursue the promulgation of their planned initiatives. Many of the students indicated verbally that their academic workload would not allow them to pursue time-intensive extracurricular activities. Thus, while our module was poised to serve the Indigenous community directly, none of the action plans developed within the module have yet been put into effect.

Multilogicality

In all of the GeoConnections modules respect for both Indigenous Knowledge and Western science as valid sources of knowledge was a prime objective. Neither knowledge system was elevated above the other intentionally. However, the GeoConnections modules were implemented within a WMS institution of higher education. Although this institution is on the lands of the Confederated Tribes and Bands of the Yakama Nation, WMS values often overshadow and take priority over the cultural values of Indigenous communities. Therefore, the structural arrangement and presentation of the GeoConnections modules may have emphasized how different our approach for GeoConnections (i.e. privileging Indigenous perspectives) was in comparison to other classes taught from a WMS perspective. The following quote from the interview data collected during the GeoConnections project illustrates the way that the participants felt GeoConnections modules were differentiated from the rest of their classes at the undergraduate level:

> *"I saw a difference. Not much of a difference. But, slight difference in the presentations or slides. The way you said the slides are different. But, yeah.,* ***I guess just the way you teach, you kind of make it more, not so technical but more of what you know.*** *Yeah because I guess that's what it means, Indigenous, it's your knowledge, what you think. [Usually] It's just from the book."*
>
> ***-Student B***

In effect, respect for both IK and WMS allowed all students, Indigenous and non-Indigenous, to participate in classroom discussions. The modules were implemented with a more

holistic emphasis based on student's contextual experiences. These contexts differed for every student, but were made explicit through discussions as well as private discussions between the instructors of the course and the students. Additionally, the main instructor for the course knew each of the students for multiple years and so she also had a nuanced understanding of the academic and personal backgrounds of the students enrolled in the course. Some students felt that WMS knowledge was inherent to all of their classes, but that the GeoConnections modules offered a contextualized approach to understanding the WMS concepts presented.

Spirituality

In the GeoConnections modules we did not try to dictate what was spiritually significant from anyone's perspective. Instead, we allowed the Climate Change report (Yakama Nation, 2016) to speak directly from the public Yakama perspective. Even though not all of the students in the class were from the Yakama nation, their understanding of the Yakama perspective was encouraged through reading excerpts from the Climate Change Adaptation Plan (Yakama Nation, 2016). Additionally, their perceptions were elevated, moving from mere understanding to respect for other cultures and their integration of their physical place with their spiritual values.

> *I haven't really been exposed to that, except for this class, so I don't know a lot about that. Taking this class, I see that* ***it means a lot to the people that live around the rivers*** *and how some of these things are disappearing.* ***It's affecting their culture*** *and things are changing.*
>
> ***-Student X***

Using IRFs for Mentoring

Mentoring has been an integral part of my graduate student experience at Purdue University. I was first given the opportunity to formally mentor as part of the "Minority Education Through Traveling and Learning in the Sciences" program and the "Sharing the Land" program (Riggs et al., 2007; Maygarden et al., 2012). These programs allowed me to teach geology to underrepresented high school students in the field along with several other geologists (other graduate students and faculty members) during summers in different parts of the United States. I

am also affiliated with the "Alliance for Graduate Education through the Professoriate" (AGEP) program at Purdue University. This program pairs more experienced graduate students with undergraduate students, usually part of the "Louis Stokes Alliance for Minority Participation" (LSAMP) program, as well as first-year graduate students. More recently, I have become a mentor for Indigenous undergraduate students through the "Indigenous iNtegration of Aquatic science and Traditional-Ecological-Knowledge for Undergraduate culturally Responsive Education" (i-NATURE). Informal mentoring has also been a natural extension of these activities because I realized immediately that people within my own department who were not part of formal mentoring programs were seeking mentors as well.

All of these experiences collectively have shaped my understanding of what it takes to mentor students from various backgrounds, academically as well as socially. As mentioned earlier, these experiences were taking place during my own progression through graduate school and as I was also searching for my own mentors. Reading literature about Indigenous research frameworks encouraged me to take an active, reflexive approach to my own mentoring style and the types of mentors I sought. Developing agency through familiarity with IRFs took me to a crossroads: I could become selfish and relegate myself to siloed thinking patterns as I saw many of the matriculating graduate students in my department do before me or I could engage with these potential mentees and bring them onto the path that I was traveling on through higher education. With great tension, I chose to help as many individuals as possible. However, as many mentors soon realize, I could not help everyone. Sometimes this was because of time constraints in my schedule but more often it was because I simply was not the best mentor for some students. As I became more experienced at mentoring, I followed the lead of others and began using my network to refer students to better-suited mentors.

"I think mentoring is a lot harder than teaching. The reason why I say that is because for me, it feels like I make deeper connections with the students [in mentoring]. When I'm teaching to a class, I'm trying to say things in a generalized sense so that everyone can understand so that everyone feels somewhat comfortable voicing their opinion. But when I'm working with an individual student, it's that one student's opinion that matters and it's very specific because they're a unique individual. I think finding that person's unique way of communicating is a lot harder than trying to communicate with a group.

Also, a lot of the mentoring relationships I've had in academia and school-- all of those [academic] topics are… not the focus of that relationship. It's like [mentees would tell me], "Yeah I'm in school, yeah I'm taking classes, yeah I have a high workload this semester, but what I really want to talk about is the stress I'm having talking to my advisor". I've had numerous mentees that were like, "I need to leave my lab and switch to a different lab" and they just didn't know how to do that. At that point, it's not me helping them understand geology concepts or anything, it's more about these ***interpersonal relationships*** *that they're having trouble with but they've never been trained or taught what are* ***the communication styles of academia****. What are the processes and protocols for that?*

For me, going back to my own experience in undergrad, I have an older sister [one of my first mentors] who was good at that. She would take me into the financial aid office, show me where to stand in line, knew which lines to fill out on the form, or which forms I would need. I started to realize there's a regular process, and when you do something wrong or you don't have the right information for them [you may not get the help you came there for]. If you ask the right question, you'll get the answer you need to move forward in the process. If you don't have this way of communicating where you know that you need ask a certain question to get an answer, you'll maybe just walk away and never realize what you need to do to continue on in the process. People get dropped off that way, they lose their financial aid. There's a lot of things that can happen paperwork wise.

That's a lot of the mentoring that I do—it's focused on these other aspects that are not explicit within higher education. I kind of offer [this type of help] out generally to the classes [I teach]. I'll say, "if you're having trouble with these things [institutional protocols], come to talk to me. I've been through a lot, I can help you with different things like that". It's only when people come to me as individuals that I'm able to really assess "what's their level of understanding, what are they trying to do, what's their goal? Am I able to help with that? Let me identify the people for them that can help them do this or who are the correct people to help them through this process?" That idea, thinking about your ***support network*** *both personally and academically, we incorporated it into one of the teaching modules at the university where GeoConnections was implemented. We had one day where that's what we did. Where they [the students] sat down and they identified people in their community, people within their personal networks that they thought would be able to help them with a research project.*

I think also it's different with mentees from underrepresented backgrounds compared to majority students. I've had both, but often the majority students are really focused on their futures. They're really interested in learning how to prepare themselves now for what position they would like in the future, either like a career or their next major or class or job or whatever. A lot of the underrepresented students I talk to, our conversations focus more on the day-to-day interactions we have with people. Say, experiences with racism or micro aggressions. Again, interpersonal relationships like problems talking to advisors or competitive atmospheres in different lab settings or just emotional feelings about their level of work ethic or level of expertise in a field. Not feeling like they know enough compared to the rest of the department or something like that. I think there's a lot of these more emotional issues that the majority students often don't really talk about [to me], at least not the students that I've [mentored]."

Darryl Reano Self-Interview, 2019, brackets and bolding added post-interview

Holistic

One of my Indigenous mentees suggested they might be interested in the Sloan Program, a program designed to offer support for Indigenous students entering graduate school. I am also affiliated with the Sloan Indigenous Graduate Program (SIGP), a "program that provides funds for the creation and operation of four regional centers that aim to foster welcoming and supportive environments that cater to the needs of indigenous students" (Sloan Indigenous Graduate Partnership, n.d.). However, the program is only implemented at certain schools around the country which would have entailed the mentee moving and leaving their cultural place. They had been told that this would be a logical next step after finishing their undergraduate degree. However, the mentee expressed some concern over leaving their home and living amongst strangers. After careful consideration with themselves, the mentee later came to me and told me that they would not be applying to the Sloan program after all.

While many mentors would have gauged their "resistance" to applying for the Sloan Program as a barrier that needed to be overcome, I saw it as a conscious decision my mentee was making for their spiritual health. For many Indigenous community members, it is impossible to leave our cultural homes and expect to remain deeply connected to our Indigenous values and customs. From that point on, our mentor/mentee conversations were redirected by the mentee towards how they could give back to their community, both as a participant in spiritual gatherings

but also as a student-researcher within the higher education community. Many of our discussions began with typical mentor/mentee question-answer dialogues (e.g. deadlines, progress reports, anticipated workloads), but these discussions often morphed into the personal dynamics of how their cultural obligations were somewhat at odds with their academic responsibilities. In this sense, my own similar cultural background as opposed to my academic background was more important for me to be an appropriate and useful mentor for this mentee (Blake-Beard et al., 2011).

Relational

Human cross-cultural communication is inherent to mentoring within WMS institutions of higher education (Blake-Beard et al., 2011). However, authentic communication relies on trust between communicators to develop meaningful relationships that allow both mentor and mentee to vulnerably share their inner thoughts and concerns, especially within Indigenous communities (Rodriguez, 1998; Smith, 1999). Often, in Indigenous communities, you develop several relationships with interrelated individuals concurrently as you are being introduced into the society. This helps ensure that different perspectives can converge on the same focal point, which is the outsider's intent, motivation, and potential benefits for being associated with the community and its members.

For many of my Indigenous mentees this necessitated meeting with their other advisors and mentors on campus. Sometimes they were current instructors of the mentees but other times they were informally connected to them through summer research projects and cultural community connections. In this way, I was simply an additional member to their academic and cultural communities. Within many Indigenous communities it is understood that everyone brings value to a relationship (i.e. mentoring relationships) and that our individual strengths are not necessarily shared between one another, necessitating the community as a broad group of people who, collectively, are better able to advise us. To truly take advantage of the strengths within our support networks it is necessary to reflect on our relationships with these individuals and learn to cohesively situate the advice we are offered. With my mentees I focus on identifying key people that have meaningful mentoring relationships, but I also do not fail to mention how I identified them and brought them into my support network in the first place. For many of my Indigenous mentees, they know what their own needs are but are hesitant to request explicit help, since that is a cultural taboo within some Indigenous communities.

Centralization of Indigenous Perspectives

One of my mentees was able to introduce me to the Yakama general tribal council. This was important for my mentee because there was a cultural obligation to introduce me to their broader (i.e. non-academic) community, especially because I was helping them with their research. During this meeting I explained who I was (my identities as a native person, as a researcher, as well as previous research I have been involved with implementing), my different roles in the community (as a teacher at a local university during implementation of the GeoConnections modules, mentoring some of the students, including Yakama community members, and also as a researcher from Purdue University), the expected outcomes from those roles. This allowed me to defer my position as a researcher to the cultural advice of the Council. I asked them to tell me if I was doing something wrong at any point or to notify me if they did not want me to be present in the community anymore. In this context, even with a shared Indigenous identity, I was respectful of the place I was in, the home of the Yakama Nation, and so I deferred all "control" to them over the research taking place under my supervision as well as my own personal affiliation(s) within the community.

Serving Indigenous community interests

While working with Indigenous mentees, it is important to me that students develop a sense of how their technical geoscientific knowledge may be incorporated into their Indigenous worldviews. Most often, this occurs when mentees are able to make connections between the technical geoscience knowledge they've acquired and the needs of their own unique communities. However, since I am not from the same Indigenous communities as most of my mentees, it is imperative that I do not overstep my boundaries with other Indigenous and non-Indigenous communities. By creating agency (Rodriguez, 1998) and fostering a reflexive mindset amongst my mentees, they are able to articulate for themselves what they perceive the needs of their communities to be. Sometimes service to Indigenous communities is direct (e.g. working within the science offices of their community's government after graduating) but other times it is less direct (e.g. inspiring the younger generation to pursue academic interests, maintaining status as an intermediary between academia and their Indigenous community). All of these potentialities are equally valid and require a certain level of personal sacrifice. For my part, I choose not to value

one pathway over the other, but I do encourage my mentees to think critically about how the career choices they make will impact themselves, their families, their communities, as well as how all these impacts fit into the sociohistorical and political contexts of our world (Rodriguez, 1998; Brayboy, 2005).

Multilogicality

During meeting with many of my Indigenous mentees, we've talked about how our Indigenous knowledge systems are such integral parts of our identity that we cannot forget about them even while we were in participating in Western institutional activities such as classes, field trip, and meetings. In addition, a lot of the WMS knowledge that we are exposed to in the classroom is taken home and shared with our families to see what their thoughts are and whether there is disagreement. In this way, the WMS knowledge shared within institutions of higher education are filtered through multiple ways of knowing.

While it was useful for each of us, individually, to reconcile our cultural worldviews with the perspective presented in the academic classroom, we had to make those connections ourselves. Amongst my Indigenous mentees I have mentored, there are differences in how they felt the cultural aspects of their educational experiences could be better respected by outsiders to their culture. Some mentees mentioned that the administration at their institutions did not make enough concession to Indigenous interests (e.g. Indigenous-controlled spaces on campus, funding for Indigenous student organizations to travel) which led to a loss of pride and engagement with their institution. Other mentees described key allies within their institution's administration who were empathetic with their concerns and who would stand up for them to other members of the administration to ensure that Indigenous concerns and interests were addressed substantially (e.g. becoming faculty sponsor for Indigenous student organizations, offering culturally relevant support through their professional networks).

Working with non-Indigenous mentees has given me different insights into how multilogicality plays an important role in mentoring relationships. Many of the non-Indigenous mentees I have worked with are apprehensive about offending me, especially when culture and Indigenous people are the topic of discussion. I make it an emphatic part of the early part of any mentoring relationship to tell mentees that I understand we are from different backgrounds and that I will not take immediate offense to anything they are willing to share. Instead, I will listen

to them and allow them to explain their reasoning for their behaviors, perceptions, and attitudes about certain topics. Creating this dialogic conversational space allows for different worldviews to come together, for us to learn from each other, but without one perspective automatically attributed more power (Rodriguez, 1998). This process is intended to allow opportunities for the mentees to develop a more complete understanding of their own needs and how to communicate, reinforcing the transformative aspect of agency (Rodriguez, 1998).

Spirituality

One of my Indigenous mentees was having a difficult experience one semester in particular. They could not concentrate and they were told by their own cultural advisors that they needed to reconnect with their environment. The cultural advisors suggested going on hikes and walks into the mountains so that they could reflect on their circumstances. After hearing them recount this experience, I offered my own adaptation of how to implement the advice within an institution of higher education. I began by explaining a similar piece of advice that I was offered by my own cultural advisors when I was younger: to respect the non-human life around me, including plants, animals, and geomorphic features (e.g. rivers, mountains). By taking this advice I was able to find a relationship with "nature" close by me at all times, even on the campus of higher educational institutions. I was able to access everyday experiences that maintained relationships with the non-human world while living my day to day life at a university. This day to day reaffirmation of Indigenous spirituality is key to maintaining Indigenous cultural identities, especially when we are displaced from the specific culturally significant places in which we usually affirm our Indigenous identities.

Using IRFs for Leading

I have had many experiences supervising people from younger generations. However, one of the most meaningful experiences I have had was when I was president of the Purdue chapter of the American Indian Science and Engineering Society (Purdue-AISES). The mission of Purdue-AISES according to the student organization constitution and bylaws, is "To nurture building of community by bridging science and technology with traditional Native values. Through its educational programs, AISES provides opportunities for American Indians and Alaska Natives to pursue studies in science, engineering, business, and other academic areas. The trained

professionals then become technologically informed leaders within the Indian community. AISES' ultimate goal is to be a catalyst for the advancement of American Indians as they seek to become self-reliant and self-determined members of society." As I reflected on my, heretofore, tangential involvement with the organization, I realized that I personally did not feel like Purdue-AISES was meeting my needs to become "self-reliant" and a "self-determined member of society". After talking with the membership as a group and approaching each member individually, I found that many people from the membership also desired more culturally relevant programming rather than opportunities for professional development that were duplicates of similar opportunities from their respective discipline-specific departments. Another issue that was identified through communication with the membership was the lack of interpersonal engagement with each other and our cultural identities. We were all part of Purdue-AISES because of our interest in Indigenous cultures (our membership is open to all Purdue University students) but there were few opportunities to actively learn about each other's cultures since many of our meetings were focused on professional development such as seminars, Western science and engineering research activities, and rote outreach activities that did not require integration of our cultural backgrounds.

With such a small active membership (about 10 regularly active members), I was able to take the time to communicate with each member directly and to consolidate our ideas for what we desired from Purdue-AISES into grant proposals. Student organizations at Purdue University are eligible for internal funds meant to encourage enrichment activities and planning for the student body of Purdue University. We identified two sources of funding: the "Graduate Student Organization Grant Allocation" board (GSOGA) as well as the "Student Fee Advisory Board" (SFAB). GSOGA is a source of funding for small projects, events, and materials that are typically less than $5,000. Our GSOGA grant proposal was focused on creating a podcast about Purdue-AISES's research accomplishments but communicated in a way that is accessible to non-academic communities. Additionally, to address the Purdue-AISES membership's need to locate each other culturally, we decided that part of the podcast programming would include introductions to each other's cultures. The SFAB grant proposal is a larger source of funding for bigger events on campus (>$15,000). For this proposal, we decided that we wanted to plan the inaugural Indigenous ArtsFest at Purdue University. The purpose of this ArtsFest is to highlight contemporary perspectives of Indigenous identities. We have invited several Indigenous DJs, an Indigenous activist/songwriter, as well as a First Nations drag queen to perform at our event, which will be

open to the entire Purdue University community. The purpose of this event is to create a culturally-inclusive space for the entire Purdue community where we can share and learn about each other. Purdue-AISES envisions an event where science, the arts (broadly), and culture intersect in meaningful and respectful ways that benefit all. Our goal with this project is to increase intercultural competency within the Purdue community as a measurable goal in alignment with Purdue University's Diversity and Inclusion initiatives.

Holistic

As leader of the Purdue-AISES organization, I began the academic year with an individualized assessment of what the current membership wanted in terms of cultural events, professional development, and outreach to the non-academic community. I did not rely on group meetings, a common form of communication among academic researchers, because it was clear that the members had many ideas that they were only willing to express in confidence among trusted individuals. As president, I felt it was my obligation to provide the space and time for these informal modes of communication to occur. Once members were able to express their needs from the Purdue-AISES student organization, I was astounded at how many people desired an interdisciplinary engagement. More specifically, while all of the members were from various science, technology, engineering, and mathematics (STEM) disciplines, there was an expressed need to develop collaborations with the liberal arts (e.g. writers and musicians) community of Purdue University. While this might seem out of line with an organization designed to meet the needs of scientists and engineers, it is certainly not misaligned with Indigenous cultural values. Since the needs of our membership lie at this intersection of cultural and academic identities, it was necessary to mold our student organization to address these needs.

Relational

In the Purdue-AISES student organization, we emphasize the importance of intergenerational contributions. In terms of our programming this meant that new students were emphatically situated within the Indigenous community at Purdue University so that their perspective was incorporated into the goals for the academic year. For many of the students, an open forum was not the place to voice their perspective and so it fell on me, as the leader, to meet with individuals to acquire individualized perspectives that were more authentic by creating

opportunities for dialogic conversation where power structures were de-emphasized. In order to do this, we had group meetings scheduled when only students (undergraduate and graduate) were allowed to attend. This is reflective, I think of the importance of informal communication (Brayboy & Castagno, 2008) within Indigenous communities. This allows individuals to express their ideas within a dialogic conversational space where ideas are both respected and challenged (Rodriguez, 1998).

Centralization of Indigenous Perspectives

During planning for the Indigenous ArtsFest, I met with several of the other cultural centers on the Purdue University campus to see if they would be interested in partially funding some of our proposed performers. While the cultural centers were happy to help, it seemed to come at a cost. Some entities were willing to invest funding in to the Indigenous ArtsFest but with the caveat that they would be able to add a performer of their choice to the Indigenous ArtsFest lineup. While this sounds collaborative in theory, one of the main things I had gathered during informal and formal conversations with AISES members was that they were excited that the list of performers for the ArtsFest were all student-generated: these were performers that spoke to the identities of our membership on a personal level. The performers that the campus entities wanted to invited served their interests but did not serve the student's interests. Reciprocity is a valued aspect of relationships with Indigenous communities and their members (Smith, 1999; Cajete, 2000; Masta, 2018). After more discussion about the purpose behind choosing the ArtsFest performers, the other campus entities agreed that it was more important for the Indigenous student body to have the final say on who was invited to perform during the ArtsFest.

Serving Indigenous community interests

Our original purpose in putting on the ArtsFest was to deliver "a diverse and inclusive event designed to highlight interactions between contemporary Indigenous communities and American culture." This project will allow Indigenous graduate students to facilitate a major cultural event that will align with the Purdue Moves goals of creating immersive diversity opportunities for the Purdue University community. The Indigenous ArtsFest will include performances by Indigenous artists but workshops will also be held to encourage discussions between the local community and the invited performers who represent various cultural groups

from different parts of the United States. These discussions will be designed using Indigenous Research frameworks that involve respectful discourse in a setting that acknowledges freedom of speech while maintaining Purdue's commitment to professionalism and even-handedness. Many of the topics presented by the invited guests will cover mainstream media topics but in relation to various communities outside of the Midwest. Research has shown that exposure to diverse perspectives encourages open-mindedness and increases cultural competency (Deardroff, 2004), which in turn makes students more employable on the global job market. However, half a year after the proposal and with much discussion of how to format the ArtsFest event, we decided that we needed to more directly focus on Indigenous perspectives and the needs of the Indigenous student body. We chose to do this by no longer focusing on interactions between Indigenous cultures and mainstream (e.g. US Midwest) cultures but to focus on contemporary Indigenous identities in an effort to reinforce the Indigenous student body's efforts to situate our cultural and academic values within contemporary society, especially the academic community of Purdue University. We felt that this created a space where all of the Purdue-AISES membership felt comfortable, accepted, and excited for sharing some of our interests interwoven within the theme of Indigenous identity.

Multilogicality

The AISES membership at Purdue University represents many diverse Indigenous cultures that are not necessarily aligned in terms of their sociopolitical worldviews. The term Indigenous is an inclusive term that is the current English representational word being used by Indigenous researchers to reference the many groups around the globe who have maintained place-based knowledge for millenia (David-Chavez, 2018). However, this essentialization can also be detrimental because not all groups considered to be Indigenous share the same worldview and values. This is also true of the membership of Purdue-AISES, because many of us are the only person from our community attending Purdue University. As a group, we've used the grants we were allocated for Purdue-AISES initiatives to explore our worldviews and their unique traits that influence the shared space created for the Purdue-AISES student organization on campus. We've neglected traditional power structures of academia by making sure that space we've created allows all members to have decision-making abilities that dictate the future directions of the student organization.

Spirituality

While we have no formal spiritual leaders on campus, the Purdue-AISES advisor, who is also the director of the Native American Educational and Cultural Center (NAECC) regularly invites Indigenous elders from around the global Indigenous community to bless many of our gatherings, to meet with students (as a group and individually), and to share their perspectives on the importance of education and its relationship to Indigenous identity. As a student organization we've also maintained the importance of spirituality as we planned our various events for the year, including the Indigenous ArtsFest. While in discussion with one of the ArtsFest performers, it was suggested that an elder lead an opening ceremony for the ArtsFest. This entailed our organization funding the travel for the elder to perform the ceremony. From our perspective this was a respectful decision, requested by the performer, but also one that we were able to not only support in discussion, but financially. This was a key factor for showing respect for the cultural norms of the performers as well as to show reciprocity for the amount of engagement we were requesting of the performers. Additionally, the presence of an Indigenous elder creates an intergenerational space for promoting our Indigenous cultural values, i.e. spirituality.

Discussion

There are many potential opportunities to connect Indigenous knowledge systems and Western science within higher education institutions of learning and research. However, it is extremely important to reflexively understand what the goals are in connecting the two (often very different) perspectives. Is the goal Indigenizing academia? Protecting traditional ways of life? There should be a purpose to connecting the two knowledge systems so that it is clear and transparent.

Many scholars, Indigenous and non-Indigenous, would argue that "it depends on the context" but I think this would be avoiding the pressing issue at hand: Western science marginalizes Indigenous knowledge (Masta, 2018). This is problematic because at the "objective" level of WMS, there is no incentive for Western scientists and researchers to connect with/to/from Indigenous knowledge systems. Defining the purpose of reaching out to each other, allows for both perspectives to be given the opportunity to decide whether the connection is something they benefit from or if the burden is too great to be taken on.

Currently, there are both formal and informal protocols and frameworks for guiding how IRFs should be used, especially by non-Indigenous people. One example is the Ethics Eskinuapimk (Battiste, 2008), also known as the Mi'kmaw Ethics Watch, created in 1999 to "ensure that Mi'kmaw people and knowledge are protected within Mi'kma'ki territory to the degree that research processes can ensure this capacity" (p. 506, Battiste, 2008). This power structure, which privileges Indigenous perspectives, allows the Indigenous community to become more involved in all stages (e.g. planning, implementing, and evaluation) of the research process.

Indigenous research frameworks are now being used to create useful communication between Indigenous communities at large with academic researchers, broadly. As more of us Indigenous scholars continue to use this holistic approach to understanding multiple perspectives surrounding pressing environmental issues, we should not overlook the usefulness of such frameworks to create better communication amongst smaller groups such as mentor/mentee relationship, classroom environments, and also organizational groups that are localized to specific interests (e.g. student organizations, corporate special interest groups, community focused groups). Creating better communication among members of our societies will create transparency which can effectively highlight new ways that disparate groups can align objectives, but also create action plans that benefit multiple interest groups.

Conclusion

Indigenous research frameworks provide powerful ways for academic researchers and scientists to understand and interact with Indigenous knowledge systems. There are many variations of IRFs but shared values among IRFs include holism, relationality, multilogicality, serving Indigenous communities' interests, centralizing Indigenous perspectives, and also respecting spirituality as an essential part of Indigenous community member's identities that cannot be disregarded. The ultimate effect of enacting IRFs correctly ensures the production of inclusive dialogue, with great transparency that supports effective communication. Communication is a key factor for the production of knowledge, the promulgation of knowledge, and the efficient storing of knowledge in both Indigenous knowledge systems and Western modern science.

Faculty members (and sometimes advanced graduate students/postdoctoral students) are required to do more than research or teach within institutions of higher education. Faculty duties

at most institutions may require that they partake in mentoring relationships (both as mentee and mentor), serve on various committees both within a department and potentially within faculty senates, and supervise graduate and/or undergraduate students. IRFs provide a framework that can be used in these multiple contexts for transparent, effective communication. As the population of students in institutions of higher education continue to diversify, it is to the benefit of academia at large to make use of opportunities to include multiple perspectives to advance Western science. In tandem with this change in the university communities, more Indigenous communities are exploring opportunities to take greater control of Western scientific research occurring amongst their community members and on Indigenous lands. Faculty members have an opportunity to conduct their research in appropriate and respectful ways that benefit Indigenous communities, just as they have opportunities to mentor students in appropriate and respectful ways, and similarly to engage their peers within academia in appropriate and respectful ways. IRFs provide a basis, centered on the perspective of historically marginalized groups, to bring equitable practices to research, teaching, mentoring, and leading groups of people. As a future faculty member myself, I am amongst the next generation of Indigenous scholars who will continue to strive for respecting multiple ways of knowing as the first step to the new generation of science, a science that respects both Indigenous knowledge and Western scientific knowledge.

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CONCLUSION & FUTURE DIRECTIONS OF RESEARCH

Authentic educational contexts developed specifically for underrepresented students are not broadly utilized within geoscience curricula in most contemporary institutions of higher education. Many Indigenous students learn later in life that science, grounded in the natural world, is something their ancestors have practiced for thousands of years and that a mastery of Western modern science can benefit their home communities within short timespans or even as products of their current educational experiences. Especially within Indigenous contexts, personal goals of students are inextricably influenced by cultural obligations to their communities. These Indigenous cultural values often have no explicit connections to the practices of Western modern science. However, if educators within academic institutions in collaboration with Indigenous stakeholders would display the links between Indigenous knowledge systems and Western scientific systems more explicitly, both Indigenous and non-Indigenous communities would receive an outstanding benefit evidenced by new approaches to thinking about how science is practiced within everyday contexts by all groups of people. For Indigenous communities this relates to the maintenance of cultural worldviews, perpetuation of Traditional practices, the reinforcement of cultural values, and promoting the long-term sustainability of natural resource management (Yakama Nation, 2016). For the academic community, this means that new approaches to solving geologic problems are discovered and utilized to find solutions to current scientific challenges and unanswered geologic questions more efficiently. These potential benefits are what have motivated these research projects.

The pilot project at Acoma Pueblo and GeoConnections were focused on creating geoscience education modules that are place-based and culturally relevant for Indigenous learners. Both of these research efforts revolve around the use of Indigenous research frameworks. Indigenous research frameworks incorporate a more holistic approach to implementing research than the traditional modes of academic research, especially within Indigenous communities (Brayboy, 2005; Wilson, 2008; Masta, 2018). This is one way for Indigenous Knowledge systems and Western scientific knowledge systems to be used in conjunction with each other. The use of Indigenous research frameworks enhanced the GeoConnections modules by recognizing the value of diverse cultural perspectives of local environments, including geology, deconstructing traditional power structures within the classroom, and also promoting the maintenance of

accountability as an academic researcher to the communities I have chosen to work with, i.e. Acoma Pueblo in New Mexico and The Confederated Tribes and Bands of the Yakama Nation in Washington State. These projects show how Indigenous research frameworks are applicable in formal as well as informal learning environments. In addition, the fourth chapter of this dissertation gives examples of how Indigenous research frameworks are applicable beyond the realms of teaching and learning. This holistic perspective of incorporating Indigenous research frameworks at multiple levels within higher education institutions will reinforce the integrity and resolve conflict that many Indigenous students contend with as holders of liminal identities.

Qualitative analysis of semi-structured interviews after implementation of the educational interventions for the Acoma pilot project and the GeoConnections modules provide evidence that elements (e.g. holism relationality, serving the interests of Indigenous communities) reflective of the use of Indigenous research framework were acknowledged by the participants as particularly impactful to their experience during implementation of the geoscience-focused activities. This can help further advance efforts to create equitable educational environments for students of various backgrounds. This is in contrast to more common practices of decontextualized, transmissive pedagogies familiar to many physical scientists. Providing context-rich, culturally relevant curricula helps to motivate and inspire learners to use science and scientific knowledge to benefit their communities and to view their environmental landscapes with renewed interest. Further, this creation of agency serves to reinforce community cultural values in ways that promote education, strengthening different community's ability to engage with Western scientists.

In my future work as a geoscience education researcher, I will continue to use both Indigenous research frameworks as well as mixed-methods approaches for designing and assessing educational interventions within geoscience and education classrooms. However, I think that it is absolutely essential that undergraduates, especially those from underrepresented backgrounds, are provided opportunities to design research questions that will be beneficial for their home communities while also gaining technical geoscience expertise through various research experiences during the academic year and summers. This will only be achieved through transformative educational and research experiences that are deliberately designed to support the individualized needs of learners.

Future directions of my research will be to collaborate on more projects that have a strong geoscientific technical research methodology but are implemented utilizing Indigenous research

frameworks. This entails a strong connection between scientists trained in Western modern science and the diverse communities in which they work. More specifically I would like to help answer some of the pressing research questions that are developing as the wider academic community is becoming aware of the benefits of using Indigenous research frameworks: Are Indigenous research frameworks viable outside of research within Indigenous communities? What are the barriers that non-Indigenous scientists face while trying to become culturally competent enough to make strong connections with the communities in which they work? Does the use of Indigenous research frameworks enhance informal learning and professional development of students and faculty members?

As Indigenous and non-Indigenous communities continue to populate and survive on our planet, we will continue to engage with each other about the most appropriate actions to take in regards to natural resource management, environmental policy, and educational objectives. In the past, these discussions have sometimes become ineffectual and even violent. GeoConnections provides an opportunity to change this trend by putting forth direct examples of how Indigenous knowledges and Western science can be utilized in tandem to serve the needs of our global community. This communicative engagement has the power to extend beyond the classroom and into the everyday lives of each and every one of us who live on the earth. We all have a relationship with the land, but not all of these relationships are valued equally. It is my hope that the knowledge shared within this dissertation will serve to subvert inequity and disenfranchisement, and will instead instill respect for the Earth and the communities around us.

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APPENDIX A. PLACE ATTACHMENT INSTRUMENT FOR ACOMA PUEBLO

Please choose the option that best describes your level of agreement with the sentence in bold. 1 means that you strongly agree with the statement in bold. 5 means that you strongly disagree with the statement in bold.

1. I feel Acoma is a part of me.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

2. Acoma is the best place for what I like to do.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

3. Acoma is very special to me.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

4. No other place can compare to Acoma.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

5. I identify strongly with Acoma.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

6. I get more satisfaction out of visiting Acoma than any other place.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

7. I am very attached to Acoma.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

8. Doing what I do at Acoma is more important to me than doing it in any other place.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

9. Visiting Acoma says a lot about who I am.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

10. I wouldn't substitute any other area for doing the types of things I do at Acoma.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

11. Acoma means a lot to me.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

12. The things I do at Acoma I would enjoy doing just as much at a similar place.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

APPENDIX B. PLACE ATTACHMENT INSTRUMENT FOR THE YAKAMA NATION

Please choose the option that best describes your level of agreement with the sentence in bold. 1 means that you strongly agree with the statement in bold. 5 means that you strongly disagree with the statement in bold.

1. I feel Yakama is a part of me.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

2. Yakama is the best place for what I like to do.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

3. Yakama is very special to me.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

4. No other place can compare to Yakama.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

5. I identify strongly with Yakama.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

6. I get more satisfaction out of visiting Yakama than any other place.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

7. I am very attached to Yakama.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

8. Doing what I do at Yakama is more important to me than doing it in any other place.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

9. Visiting Yakama says a lot about who I am.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

10. I wouldn't substitute any other area for doing the types of things I do at Yakama.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

11. Yakama means a lot to me.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

12. The things I do at Yakama I would enjoy doing just as much at a similar place.

1=strongly agree 2=agree 3=neutral 4=disagree 5=strongly disagree

APPENDIX C. LEARNING OBJECTIVES FOR GEOSCIENCE EDUCATION MODULES

Description:

These three Geoscience Education Modules (GEMs) are designed to create more relevance between introductory environmental geoscience concepts and Indigenous perspectives of the environment. These modules have been contextualized for the Confederated Band and Tribes of the Yakama Nation in Washington state. The primary topics covered in these modules include climate change, carbon sequestration, the geomorphology of rivers, and scientific communication.

Learning Objectives:

1. Describe how scientific views about climate change are validated and supported.
2. Describe how climate change is currently impacting the Pacific Northwest in the United States, including Indigenous communities along the Columbia River.
3. Describe carbon sequestration, including the geochemical processes that are necessary to transform atmospheric CO2 into a solid phase.
4. Compare $\boldsymbol{\delta^{18}O}$ and $\boldsymbol{\delta^{13}C}$ values within carbonate minerals found in the Grande Ronde Basalt by plotting them graphically using Excel.
5. Describe the different variables that impact how rivers form and identify geomorphological features of the Yakima River using Google Earth.
6. Describe the cultural value of the Yakima River to Indigenous communities in the Pacific Northwest of the United States.
7. Identify technical and non-technical skills used by geoscientists to communicate with various sectors of society.
8. Be able to describe your own communication style, including its relative strengths and weaknesses.
9. Use your self-identified support network to create an action plan to mitigate climate change in the Pacific Northwest of the United States.

Schedule:

Columbia River Basalt Module	
Activity	**Learning Objectives Covered**
Climate Change from Different Perspectives	1, 2, 6
Wallula Basalt Pilot Project	1, 2, 3, 4, 6
Closed Systems	3, 4
Yakima River Module	
Activity	**Learning Objectives Covered**
Identifying River Features using Google Earth	2, 5, 6
Climate Change in the Pacific Northwest of the United States	1, 2, 6
Stream Table Activity	2, 5, 6
Policy and Communication Module	
Activity	**Learning Objectives Covered**
Geoscience Careers and Communication Styles	1, 6, 7, 8, 9
Support Networks	6, 7, 8, 9
Climate Change Adaptation Plan	2, 6, 7, 9

Resources:

Houlton, H. (2015). Geoscience Career Master's Preparation Survey Report, American Geosciences Institute.

Raven, P. H., Hassenzahl, D. M., Hager, M. C., Gift, N. Y., & Berg L. B. (2015). *Environment 9th Edition*. United States of America: John Wiley and Sons, Inc.

Matter, J. M. & Kelemen, P. B. (2009). Permanent storage of carbon dioxide in geological reservoirs by mineral carbonation. *Nature Geoscience*, 3, 837-841. DOI: 10.1038/NGE0683

McGrail, B. P., Schaef, H. T., Spane, F. A., Cliff, J. B., Qafoku, O., Horner, J. A., Thompson, C. J., Owen, A. T., & Sullivan, C. E. (2017). Field validation of supercritical co2 reactivity with basalts. *Environmental Science & Technology Letters*, 4, 6-10. DOI: 10.1021/acs.estlett.6b000387

Yakama Nation (2016). Climate Adaptation Plan for the Territories of the Yakama Nation Version 1 (April 2016).

APPENDIX D. GEOCONNECTIONS IRB APPROVAL MEMO

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	JONATHAN HARBOR HOVD
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	03/24/2017
Committee Action:	**Expedited Approval - Category**(6) (7)
IRB Approval Date	03/24/2017
IRB Protocol #	1701018726
Study Title	GeoConnections: Evaluating the Impact of A Place-Based, Culturally-Relevant Geoscience Learning Module on Undergraduate Students: Connections to Geoscience Concepts and Careers PART1
Expiration Date	03/23/2018
Subjects Approved:	50

The above-referenced protocol has been approved by the Purdue IRB. This approval permits the recruitment of subjects up to the number indicated on the application and the conduct of the research as it is approved.

The IRB approved and dated consent, assent, and information form(s) for this protocol are in the Attachments section of this protocol in CoeusLite. Subjects who sign a consent form must be given a signed copy to take home with them. Information forms should not be signed.

Record Keeping: The PI is responsible for keeping all regulated documents, including IRB correspondence such as this letter, approved study documents, and signed consent forms for at least three (3) years following protocol closure for audit purposes. Documents regulated by HIPAA, such as Authorizations, must be maintained for six (6) years. If the PI leaves Purdue during this time, a copy of the regulatory file must be left with a designated records custodian, and the identity of this custodian must be communicated to the IRB.

Change of Institutions: If the PI leaves Purdue, the study must be closed or the PI must be replaced on the study through the Amendment process. If the PI wants to transfer the study to another institution, please contact the IRB to make arrangements for the transfer.

Changes to the approved protocol: A change to any aspect of this protocol must be approved by the IRB before it is implemented, except when necessary to eliminate apparent immediate hazards to the subject. In such situations, the IRB should be notified immediately. To request a change, submit an Amendment to the IRB through CoeusLite.

Continuing Review/Study Closure: No human subject research may be conducted without IRB approval. IRB approval for this study expires on the expiration date set out above. The study must be close or re-reviewed (aka continuing review) and approved by the IRB before the expiration date passes. Both Continuing Review and Closure may be requested through CoeusLite.

Unanticipated Problems/Adverse Events: Unanticipated problems involving risks to subjects or others, serious adverse events, and serious noncompliance with the approved protocol must be reported to the IRB immediately through CoeusLite. All other adverse events and minor protocol deviations should be reported at the time of Continuing Review.

Ernest C. Young Hall, 10th Floor - 155 S. Grant St. - West Lafayette, IN 47907-2114 - (765) 494-5942 - Fax: (765) 494-9911