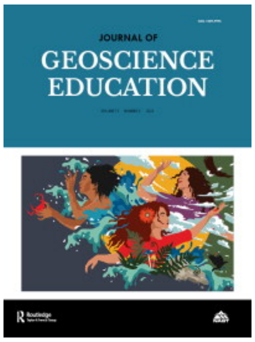

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Importance of centering traditional knowledge and Indigenous culture in geoscience education

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ABSTRACT

Traditional Knowledge (TK) is a qualitative and quantitative living body of knowledge developed locally and regionally across generations over thousands of years. This study aims to show through authentic voice the importance of centering TK systems and cultural needs to provide equitable geoscience education programs. TK can be communicated through a variety of methods, such as story and song, dance, paintings, carvings, structures, and textiles. TK is interdisciplinary within anthropological and ecological subsistence and provide enhanced cultural and spiritual context. Research findings are enhanced by the exploratory and inquiry-based design of TK and provide insight into the anthropogenic impacts on the environment allowing researchers to gain a rich understanding of human behaviors and patterns when collecting and analyzing data. This study examines factors influencing Indigenous students' participation and retention in the geosciences, specifically gauging opinions on the incorporation of TK systems into geoscience education. Data was collected using an electronic survey to identify factors that inform students' decision to enter geoscience disciplines and better understand the importance of role models and mentors for retention. Our findings indicate that Indigenous students were interested in using both TK and Western science in geoscience learning spaces, Indigenous role models played an important role in sense of belonging and identity in the geosciences, and the incorporation of culture into learning experiences played an important role in retention. Findings from this study, if operationalized, would allow geoscience departments to increase retention of Indigenous students and faculty, provide equitable educational opportunities, and to better understand how to effect cultural change in the geosciences by providing a welcoming and affirming space for Indigenous scholars.

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Traditional knowledge; geoscience; indigenous-education; culture role models; equitable education

Introduction

For decades there has been research focused on the lack of diversity in the geosciences, followed by many discussions around interventions with very little progress in mitigating the barriers in a meaningful way such that the number of Indigenous scholars in these fields has not changed despite an increase in racial diversity in the geosciences (Beane et al., 2021; MacPhee et al., 2013). In this study we use de Costa (2014) definition of Indigenous as being based upon an individual's descent, cultural requirements, or by how they choose to self-identify (de Costa, 2014). Deficient racial representation of students in STEM is often attributed to biased stereotypes about intelligence and lack of academic preparedness based on race (McGee et al., 2017; McGee & Martin, 2011; Trytten et al., 2012). A 2019 longitudinal survey sampled 150 STEM professors and revealed racial achievement gaps in courses taught by biased faculty were twice as large as the achievement gaps in courses taught by unbiased faculty (Canning et al., 2019). The described achievement gaps are actually lapses in the offering of equitable educational opportunities to diverse students. When examining the literature on the lack of diversity education in the sciences, one will find a multitude of deficit-based language used to describe diverse students, faculty, and the communities that they represent (Davis & Museus, 2019; Mortim, 2018; Wang et al., 2021). Niemann (1999) states that students "may fall victim to stereotype threat" which is described when a vulnerable population internalizes negative mainstream stereotypes, in this instance diverse scholars lacking a sense of belonging, self-efficacy, and/or struggling with imposter syndrome. Few studies examine the negative impacts of racism, stereotype threat, and stigma within academic climates as a significant contributor to low retention rates, exclusive positions of power, biased policies and procedures, lack of cultural awareness, and/or apathy toward diverse students (Niemann, 1999). The lack of retention of diverse scholars is frequently attributed to lack of interest in Western science, however, over the last decade,

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studies have systematically dispelled this stereotype (Griffith, 2010; Williams & Shipley, 2018). Research has shown that these negative stereotypes foster a sense of *lack of belongingness* (Belanger et al., 2020) and highlights that female students and students of color experience gender bias and stereotyping within these negative climates (Liben & Coyle, 2014; McKinnon & O'Connell, 2020) resulting in failure to retain diverse students.

Geoscience is a field-based research discipline that relies heavily on hands-on, inquiry-based experiences to provide students with the opportunity to apply course knowledge and to further develop critical thinking skills in real-world, professionally low risk activities in a learning environment (Almquist et al., 2011; Arthurs, 2019). While there is little doubt as to the importance of field experiences, it conversely presents barriers for diverse students for a variety of reasons. Specifically for Indigenous students, the core issue is a lack of understanding or acknowledgement of their culture and cultural responsibility to the environment. Western culture has established the framework on how field experiences are designed and implemented, which is constructed around ableism, economic exclusion, cultural exclusion, hostile climates, and accessibility issues (Atchison et al., 2019; Carabajal & Atchison, 2020; Kingsbury et al., 2020; Marín-Spiotta et al., 2020; Peterson, 2021).

Field research experiences often take place during the summer when students are perceived as having "time to participate"; there is little consideration to cultural responsibilities, specifically for Indigenous students, who may have to be home to help harvest cultural and traditional use resources, manage family farms, or take care of their "extended" family (Smythe & Peele, 2021). Additional factors negatively impacting Indigenous students' participation in field research are the economic need to financially support themselves and/or their family, the lack of student access to field equipment, the feelings of isolation in a setting where they are underrepresented, the impacts of isolation on students' sense of safety and security, and how these feelings are compounded by low self-efficacy as a field scientist and the struggle to possess a sense of belonging (Freeman et al., 2007; Martinez-Cola, 2020; Taylor, 2018; White et al., 2019).

Traditional knowledge is geoscience

TK from all Indigenous communities share a common worldview that all things in the natural environment have spiritual values, have meaning, are connected, and deserve respect (Bauer, 2007). However, TK is diverse and can diverge amongst different communities and cultures, with each possessing distinct protocols, histories, languages, and cultural practices shaped by the local and regional environment. The Bureau of Indian Affairs' federal register lists 574 respective Tribes in the U.S. (Bureau of Indian Affair, Interior, 2021). Irrespective of the number of tribal nations, Western society often collapses the multitude of Indigenous identities into a single monolithic identity such that any one Indigenous individual is expected to represent an entire population (Champagne, 2021; Erving & Smith, 2022; Smythe et al., 2020). If meaningful relationships are to be established with Indigenous students, scholars, colleagues, or with tribal nation leaders, it is imperative that an understanding and acknowledgement of the variety of beliefs, values, and perceptions of TK is conveyed, and that the practice of merging cultural identities and realities into a single interpretation is careless and harmful and will no longer occur (Barnhardt & Kawagley, 2005). TK is deeply grounded in local and regional knowledge, and deeply rooted in cultural traditions of Indigenous people over millennia. It is comprised of intellectual knowledge that is expressed through language, artistic expression, dance, music, names, medicines and remedies, stories, and so much more. TK encompasses multiple disciplines simultaneously such as geoscience, social science, spirituality, and health into a single concept and body of knowledge (Berkes et al., 2000; CEMA, 2015; Downes, 2000; Hoagland, 2017; Ragavan, 2001; Smythe et al., 2020).

Every culture has its own science (Ogawa,1995; Snively & Corsiglia, 2001). Ogawa (1995, pg. 585) defines Indigenous science as "a culture-dependent collective rational perceiving of reality," where "collective" means held in sufficiently similar form by many persons to allow effective communication, but independent of any particular mind or set of minds (Ogawa,1995). The perception that TK is misaligned and incompatible with Western science has an exclusionary effect, particularly where information is shared and authorized by the scientific community and is prioritized in favor of "pure" disciplines and/or "pure" sciences (Berkes et al., 2000; Durie, 2004; Iaccarino, 2003; Martin, 2012; Smythe et al., 2020). The fundamental distinction between TK and Western science is in the grounding of knowledge in a Western perspective, disconnected from the holistic values, culture, and perspectives that are considered in TK systems (Smythe et al., 2020). This difference can present challenges for non-Natives to comprehend and value TK systems and Indigenous science. Only when the presumed hierarchy between Western science and TK is removed can the true value of both knowledge systems can be realized, and the power of coupling multiple knowledge systems can be used as an innovative tool providing powerful solutions to complex scientific problems (Aikenhead & Ogawa, 2007; Hoagland, 2017; Smythe et al., 2017, 2020). Aligning these two knowledge systems can be challenging due to the distinction in evaluation methodologies, in ways of capturing data, in the understanding of intellectual property, the requirements for transparency, and for obtaining permissions to discuss and disseminate TK. However, students exposed to multiple knowledge systems will have an advantage in developing advanced critical thinking and reasoning skills (Cobern & Loving, 2001; Smythe et al., 2020). Inclusion of TK systems, especially when considering local science phenomena, provides rich historical knowledge dating back thousands of years and enhances research findings by providing environmental and cultural context (Smythe et al., 2020).

We have developed a proposed model for integrated learning of multiple knowledge systems using TK and

Western science with each discrete component denoted inside the black circle (Kelsey, 2003). At the center of the model is Traditional Knowledge a component at the core of Indigenous students' worldviews and informs meaning making, here TK encompasses all sub-disciplines simultaneously along with cultural values and spirituality. In the second layer of the model, Western knowledge is represented by distinct disciplines here, all disciplines are linked to one another. In contrast, Western science typically considers distinct disciplines to be siloed as a "pure science" from other disciplines. For example, knowledge about chemistry will impact a students' understanding of biology concepts. In the outermost ring, is the individual student and development of critical thinking skills from using multiple knowledges to teach science concepts. Early development of critical thinking skills enables students to better interrogate scientific factors using multiple complex concepts (Figure 1).

Purpose of study

The purpose of this study was to identify and understand retention factors impacting Indigenous students in the geosciences. The identification of regional and national factors, grounded in tribal protocols and traditional ways of knowing, will provide a framework for the design and implementation of inclusive geoscience programs and research opportunities. The study focused on four factors to gain a better understanding of the motivators for Indigenous students to enter into STEM fields, specifically geoscience; (1) factors that influence career choice, (2) factors that influence discipline choice, (3) the influence of culture in student choices, and (4) educational goals and aspirations of students engaged in the geosciences.

Study population and setting

The setting of this project was a nationally disseminated online survey focused on Indigenous geoscience scholars, faculty, staff, researchers, students, without regard for age, gender, or ethnicity. A total of 116 respondents completed the survey. Gender diversity of respondent consisted of 88.57% female, 8.57%, male, and 2.86% identified as other. Ages of individuals completing the survey ranged between 18-69, and their self-reported ethnic identities were American Indian/Alaska Native, 66.67%, Hispanic, Chicano, or Latino, 2.08%, Native Hawaiian/Pacific Islander, 5.13%, and Asian

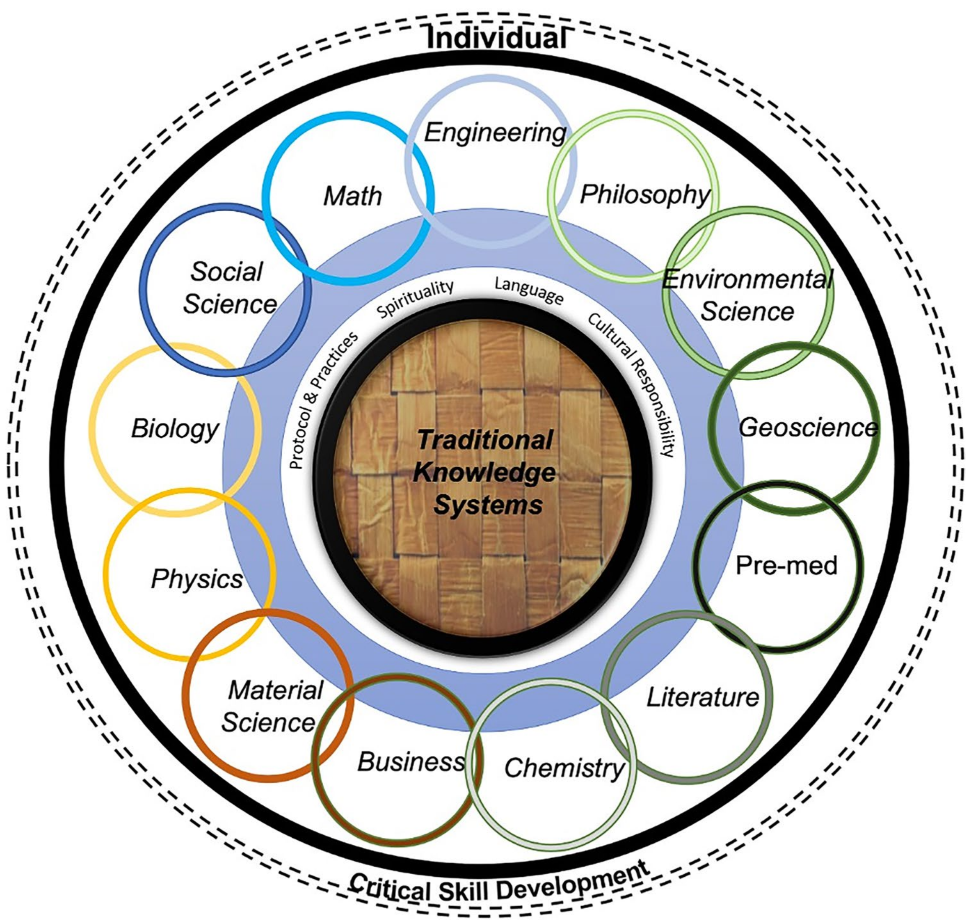

Figure 1. Model of integrated learning using TK and Western science each with discrete components denoted inside the black circle. The center of the model is the TK component as the core of Indigenous students worldviews and meaning making, encompassing all disciplines simultaneously along with cultural values and spirituality. The second component is Western science, here each discipline is linked to other disciplines as knowledge of various disciplines impacts students interpretations of learned knowledge and meaning making. In the outermost ring, is the individual student and development of critical thinking skills from using integrated learning pedagogies.

Table 1. Summary of respondent demographics of those who completed the survey. Data demonstrates ethnic identity, level of education, gender, and discipline choice.

Demographics of survey respondents	
Gender	Percent
Women	88.57%
Men	8.57%
Age Range	18-69
Level of Education	
Pre-college	31.36%
Associate	11.11%
Bachelor	24.07%
Masters	16.67%
Ph.D.	1.85%
Certificate program	14.81%
Ethnicity	
Native American/Alaska Native	66.67%
Haida	23.0%
Yakima, Navajo (Diné)	13.0%
Ojibwe	8.0%
Tlingit, Tsimshian, Nez Perce, Paiute, Choctaw, Apache, Sioux, Yaquri, Umatilla, Cherokee	3.0%
Native Hawaiian/Pacific Islander	5.13%
Asian	2.56%
African American	2.56%

or African American, 2.56%. Current level of education of participants included pre-college, 31.46%, with an associate degree, 11.11%, with bachelor's degree, 24.07%, with master's degrees, 16.67%, Ph.D., 1.85%, and with trade school certificates, 14.81% (Table 1).

Research design

This study used a mixed methods approach to allow for the integration of rigorous quantitative and qualitative approaches for a comprehensive understanding of the research questions (Carroll Steward et al., 2021; Plano Clark & Ivankova, 2019). This study follows a mixed method design using multiple data sources analyzed using both qualitative and quantitative methods to address weaknesses in utilizing a single research method (Plano Clark & Ivankova, 2019). The study was distributed through social media, Facebook and Twitter, as well as by direct email to faculty, student, community members, and to directors of Indigenous science education programs in an effort to reach as many respondents as possible.

Qualitative and quantitative data were obtained through an online survey using Qualtrics software version XM (Qualtrics, Provo, UT, USA) which included discussion questions. To gain a better understanding of the positive factors that attract and recruit Indigenous students into geoscience disciplines, we distributed a national Qualtrics XM survey and conducted personal interviews, allowing us to examine the previously stated questions.

Methods

Survey tool

For the purpose of this study, participants were asked to identify as Indigenous with the following cultural identifiers: Native American, Alaska Native, Pacific Islander and Mexican. Assessment of attitudes and perceptions as to how respondents defined TK, geoscience, choice of science discipline, role of culture, and factors influencing these opinions was analyzed from responses to an on-line survey broadly distributed using Qualtrics. The survey was modified from previously published research focusing on geoscience disciplines rather than evolutionary biology, the survey did not inquire as to sexual or religious orientation (Mead et al., 2015; Smythe et al., 2020).

The survey asked respondents to select their best answer to a series of forty-one multiple choice questions and to provide statements to open ended questions. This study considered how educational background, gender, age, cultural influence, and peer/mentor interactions influenced career and discipline choice.

Open-ended questions or statements were used to prevent influencing responses of survey participants. The focus of the project was on the geosciences; however, to better understand what discipline survey respondents were interested in, a broad array of science disciplines were categorized across thirteen sub-disciplines: ecology, medical science, environmental, geoscience, biology, oceanography, geology, molecular biology, microbiology, engineering, mathematics, evolutionary science, and others, with an opportunity to insert a discipline in a provided text box.

Questions and statements followed a Likert format and were scaled from 1 through 5 and developed to address preliminary questions about an individual's educational background, their perception of the quality of education received, factors influencing discipline selection, information about individuals or other sources of influence for career selection, and the impact culture and traditions had on choices and opinions (Likert, 1932). All data collected followed Michigan State University Institutional Review Board guidelines, IRB #i040365.

To better elucidate perspectives, we conducted one focus group discussion in which the group was divided into four groups of 19 participants to better capture responses. The total number of focus group participants was 76. To better understand perspectives of Indigenous geoscientists from various tribal nations, on the importance of providing culturally aligned and ethical geoscience education, and the impacts respondents thought coupling these TK with Western knowledge systems. Research questions discussed in focus groups were: (1) What is a scientist? (2) Has coupling TK with Western science had a positive impact on you as an Indigenous scientist?

Analysis of qualitative data

Qualitative data was collected from focus group responses to two discussion questions. Responses were used to construct an open coding schema organized into a matrix, and the constant comparison method (Glaser, 1965) was used to analyze focus group responses in the matrix. First round coding consisted of open coding as described by Saldana (2013), followed by axial coding to sort data into sub-category topics within the context of each question. Finally, line-by-line coding was used to establish themes of which theme frequency was determined by tabulating responses within each theme (Glaser, 1978, 1992; Glaser & Strauss, 1967; Strauss, 1987).

Results

Respondents were asked to identify the science discipline they were interested in or pursuing; biology was selected by 41% of respondents, of which included the sub-disciplines of ecology, evolution, microbiology, molecular biology, environmental and fishery sciences. Other disciplines indicated were, sociology, 7.32%, TK, engineering, chemistry, and business, 4.80%, political, computer science, healthcare, and art, 2.43%, and undecided, 19.5% (Table 2).

Respondents were asked to describe their pre-college (K-12) education and the type of school they attended from a list of provided terms to better understand educational experiences. The most abundant response was that respondents attended public school (30%) that they described as average (20%) and economically poor (15% combining poor and low-income responses). Few students were exposed to culturally aligned (3%) K-12 education, which is a well documented trend across the U.S. (Nicholas, 2018; Ogar et al., 2020; Wheeler et al., 2020) .

Respondents were asked to describe their current profession or employment status, to report their career stage, in order to better understand if career stage might impact survey responses. Career stage of survey respondents was comprised of students (59%), pre-college to graduate, tribal employees (11%), retirees (5%), and a variety of other professions (24% collectively), such as teachers, government, industry and consultant (Figure 2).

Table 2. Summary of disciplines participants engaged in as discrete disciplines as accumulative.

Discipline	% per Discipline	Accumulative %
Evolution, microbiology, molecular biology, environmental and fishery sciences); Geology; Chemistry; Biochemistry; Arts; Computer Science; Business	2.13%	25.53%
Traditional Knowledge; Behavior Science; Public Health	4.26%	12.77%
Ecology; Engineering; Fisheries	6.38%	19.15%
Biology	10.64%	10.64%
Environmental Science	12.77%	12.77%

Factors influencing career choice

Personal factors

Personal factors and influences were separated into four distinct constructs. Construct categories were (1) self-identity; (2) influence from friends, family, and community; (3) influence from teachers, mentors, other educators, and coworkers; and (4) influences from culture/tradition and pop culture/media.

Indigenous students' interest in a STEM discipline for a career choice was strongly influenced by their ability to identify with role models and peers with the same ethnic (22.41%) and socio-economic status (23.87%). Students who could self-identify as a scientist (35.29%) were more likely to choose a career related to a STEM discipline. Participants chose careers they believed would allow them to make a positive difference within their tribal community (51.85%), followed by enjoyment of their career (25.93%), and by salary (11.11%). Indigenous students consistently stated that they wanted to "advocate for their communities" in regard

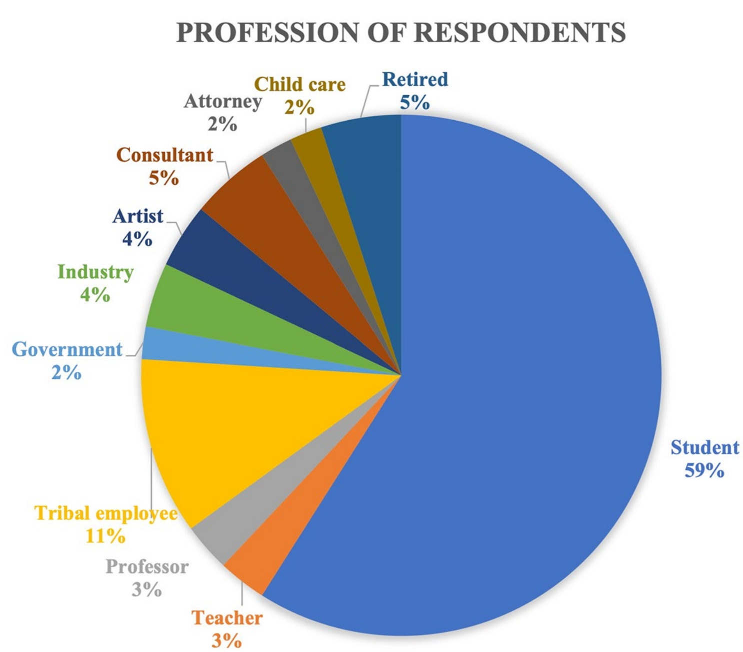

Figure 2. Professional distribution of survey respondents, where 59% of respondents were students, 11% tribal employees, 5% consultants and retired, 4% artists and industry, 3% professor and teacher, and 2% attorney, childcare, government.

to education equity, environmental and human health, and access to cultural and traditional use materials. In contrast, white students express an interest in science due to a "general curiosity about the world, for a high paying job/career, for an intellectual challenge, an interest in making new discoveries, and because it made students seem intelligent" (Hawes, 2012).

The influence of family and friends (34.02%) was rated as a key factor for career choice, with 13.41% of respondents rating family support as very important for career choice. Peers and siblings had little influence on career choice. Survey participants felt that their parents/guardian, mentors, and role models strongly supported their STEM career choice.

Mentors' and teachers' influence on career choice in a STEM discipline rated important for 35.33% of respondents. A mentor that was a scientist had a strong influence on students' decisions to pursue a career in a STEM discipline, with 15.85% stating that it was very important to have a scientist role model. Role models played a key role with 23.91% of respondents stating that they would change their career if their role model disapproved of their career choice. Participants indicated that they became interested in STEM from the influence of their teachers, role models, and mentors, and reported the importance that these individuals played in students' career choice (Figure 3).

To demonstrate the importance of mentors we asked pre-college students between 5th and 12th grade from a tribal school to describe a "scientist" using three words. All students had not been exposed to an Indigenous role model or mentor prior to the study responded with the same seven terms: "white, male, lab coat, glasses, crazy hair, bald, and old." Notably, they did not identify any gender or racial diversity, stating male and white in their descriptions. Conversely, students who had engaged with an Indigenous role model, mentor, or cultural practitioner from a variety of scientific disciplines and tribal affiliations exhibited an expanded vocabulary when asked to describe a scientist. They chose words that reflected gender, cultural, and racial diversity: "smart, female, male, experiment, college, respectful (cultural value), Native, lab coat, role model, genius, job, like, awesome, tester," as well as personal descriptors indicating that a student specifically identified as a scientist and used terms to describe themselves: "short, tall, curly hair" (Figure 4).

Cultural factors

When asked if tradition and culture were important when determining career choice, (38%) of respondents said it was very true that culture impacted career choice and (22%) of respondents said it was true (Figure 5). In contrast, mainstream culture, defined as pop culture, religion, and media, were reported to be of low importance (2.44%) for career choice. When asked about the impacts of Indigenous culture on career choice a significant portion of participants (70.20%) indicated that they consider themselves to be culturally aligned and that their culture directly influenced their career and educational decisions (51.0%) with 73.8% stating that they actively participate in cultural activities (73.80%). We found that a considerable portion of respondents are already actively incorporating TK into their STEM discipline (52.13%) and believe that coupling these two knowledge systems allows them to be better scientists. When asked if respondents considered themselves cultural by actively engaging in cultural beliefs and practices, 55.87% overall indicated that they were cultural, with 35.29% identifying as very cultural, and 20.50% as cultural (Figure 6). There are a variety of reasons why 45% of respondents do not consider themselves cultural, all of which likely stem from intergenerational traumas manifesting as fear and shame when engaging in cultural activities, access to cultural practices, and/or lack of cultural practitioners willing to shared traditional knowledge. Further investigation is needed to clearly elucidate the factors participants do not consider themselves cultural.

Indigenous students engaged in research opportunities centering Indigenous identity, cultural protocols and practices and that acknowledged TK reported feeling more self-confident; more active engagement with complex political, scientific, and cultural issues; and a strong sense of responsibility to their tribal communities. Students participating in summer internships that were culturally aligned and designed to provide cultural days each week reported satisfaction with a balance in their educational/research opportunities and their cultural responsibilities. Cultural days are provided to allow interns to engage in cultural activities that they engage in with their family, community, or as aligned with their cultural responsibility, activities may include harvesting, planting, caretaking, food preparation, etc.

Respondents were asked to identify the reason for their career choice, with a majority (52%) choosing a career so that they could make a positive difference or contribute to their tribal community. The two notable responses wanted a job they would enjoy (26%), and a good salary (11.11%) (Figure 7). These responses align with core cultural values identified across tribal nations with the notion that an individual's self identity is secondary to their identity as a member of whole, such as tribal nation or community, therefore career choice is driven by overall impacts on the community.

Discussion

A common theme of respondents across tribal nations was that geoscience careers would increase the quality of life for their tribal community (51.85%) with an expressed interest in empowering their community's ability to advocate for themselves in regard to environmental health and safety especially when engaging with external interests, industry, state, or federal governments, about use of natural resources on or near tribal lands.

It is evident from this study that culturally relevant mentors, teachers, and cultural practitioners have a significant impact (35.33%) on students' interest in geoscience disciplines. Students exhibited increased self-efficacy (35.29%)

Figure 3. Graphic illustration of personal factors influencing career/discipline choice. 33% of respondents indicated that mentors and teachers had a strong impact on career choice. 15.85% stated that it was very important to have a STEM role model. 23.91% of respondents stated that they would change careers if their role model disapproved of their career choice.

in being a scientist after they had interactions with a culturally relevant role model, and expressed the importance of mentor/role model relationships as being vital for their retention. These relationships allowed students the ability to maintain their cultural identity as a "Native scientist" which was important (70.20%) to respondents. Respondents overwhelmingly noted tokenization as a barrier related to their identity as a scientist. Tokenization is prolific in

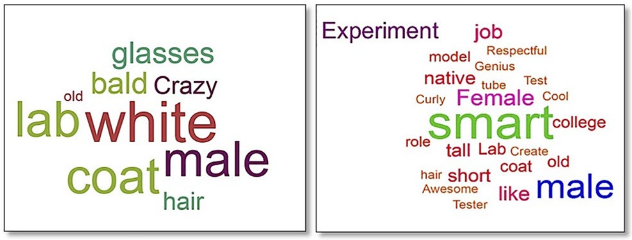

Figure 4. Word cloud demonstrating the difference in word choice Indigenous students used to describe a scientist. A. Word choice of Indigenous students who had never engaged with an Indigenous role model or mentor. B. Word choice of Indigenous students who had engaged with an Indigenous role model, mentor, or cultural practitioner.

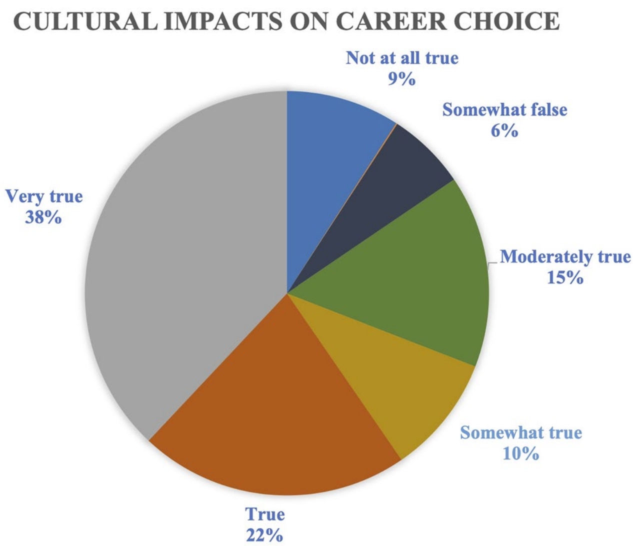

Figure 5. Graphic illustration of responses when respondents were asked if tradition and culture were an important influencing when choosing a career/ discipline. 38% of respondents said it was very true that culture played a role in career choice, 22% selected true, with only 9% selecting that culture played no role in career choice.

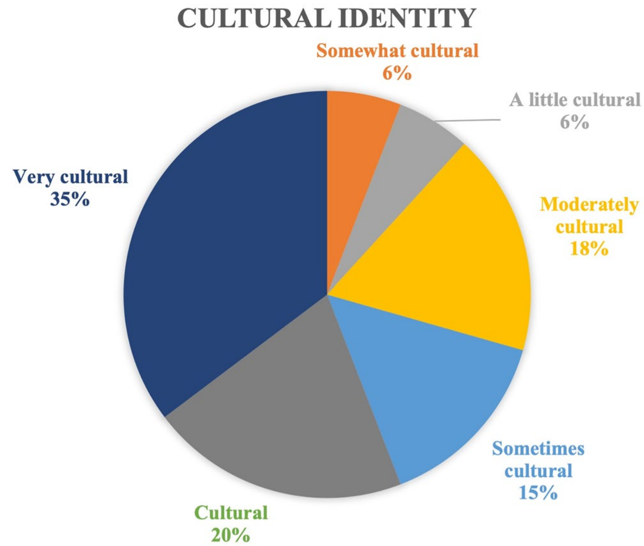

Figure 6. Graphic illustration of Indigenous respondents responses to the question of engagement in their cultural beliefs and practices. 35% of respondents selected that they consider themselves very cultural, and only 6% considering themselves somewhat cultural. Overall 55% consider themselves engaged in cultural practices.

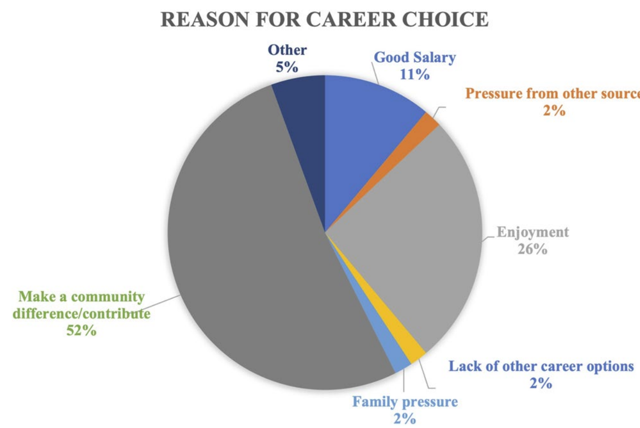

Figure 7. Graphic illustration of respondents reason for selecting their chosen career. 52% of respondents selected their career in order to make a difference in their community, 26% selected a career they would enjoy, 11% selected a career for a good salary.

mainstream society and is a form of covert violence toward diverse scholars making one feel as though they don't belong in science and that their only value is to meet a diversity requirement (Gillespie, 2020; Haskins et al., 2013; Hubain et al., 2016). Behaviors of tokenization suggest a lack of intellectual scholarship which is signaled to students and faculty when they are introduced solely based upon their racial identity rather than by their official academic title.

There is a need to teach diverse students using culturally relevant and aligned science curriculum as well as a need to address and change the deficit-based language used to describe knowledge systems that are not Western science. How do we as scientists, who by definition is someone who studies the world to gain a better understanding, dismiss knowledge systems that are tens of thousands of years old and still hold true today? We must consider whether we are being "good scientists" through the practice of dismissal of knowledge systems that are not Western? All of these factors have an cumulative impact on students' mental, emotional, and intellectual well-being making academic endeavors all the more challenging. In general, students consistently demonstrate a lack of interest in science education when taught from an unfamiliar world view and this is particularly true for Indigenous students who have a relational rather then contractual worldview (Hansson, 2014; Waziyatawin, 2012). Science education taught solely from a Western and unfamiliar worldview without including TK systems, Indigenous role models to mentor students, or cultural practitioners will continue to fail to provide equitable educational opportunities for not only Indigenous but all of their students. There is an urgent need for educators to provide equitable education opportunities by implementing more effective pedagogical practices for all students (Rodriguez, 2015).

This study provided a platform for Indigenous respondents to identify and discuss difficulties coupling TK and STEM in a safe and secure space and provide input as to how to converge these two knowledge systems to support educators in the development of ethical and culturally relevant pedagogical strategies to increase academic success of Indigenous students. Almost half (52.12%) of the respondents noted that they are actively engaged in incorporating TK into their geoscience disciplines and practices. There is evidence that coupling knowledge systems, TK and Western, has benefits such as fostering improved communication and collaboration across both disciplines and cultures, encourages innovation, creativity, and problem solving, and further develops students' critical thinking skills (Smythe et al., 2020, 2021; Verma et al., 2016).

Responses in this study clearly reflected the distinct cultural differences in the worldviews of Indigenous populations and that of Western society. These differences reinforce the importance of educators understanding these differences to allow them to become better educators to all students in their classroom. In addition, gaining an understanding of multiple knowledge systems and worldviews provides a valuable tool for educators as they design and implement culturally relevant and equitable science pedagogy (Brayboy & Castagno, 2009; Kawagley et al., 1998; Kimmerer, 2002). A theme that emerged from responses was that both TK and Western science are both distinct knowledge systems and each are necessary for environmental and human health and safety. However, there were hesitations from the Indigenous respondents in stating that TK and Western science were similar, highlighting the differences in worldviews between Indigenous and non-Indigenous cultures. Indigenous respondents defined TK as observing the natural world and learning how to adapt for survival, in contrast Western science was described as a field that was an addition to what was already known from elders. These differences reflect the obstacles discussed in merging these two fields together without first having an in-depth understanding of each knowledge system (Snively, 1995; Snively & Corsiglia, 2001). Participants stated that they felt that their Indigenous voices were marginalized in academic settings making it challenging to persist in the geosciences. Despite challenges that emerged in discussion it was proposed by respondents that integration of TK and Western science should be done and would benefit the geoscience by providing important knowledge about ecological sustainability and environmental integrity (Price et al., 2008; Siegal, 1997). As more Western scientists, policy makers, and governments continue to acknowledge and implement TK to mitigate the impact of anthropogenic activity on the environment, it is critical that students learn using integrated learning pedagogies about these knowledge systems and methods to fully understand the impact of these two knowledge systems on the environment and society.

Limitations of study

This study was limited by the small number (n = 116) of survey respondents as there are relatively low number of Indigenous geoscience scholars in academic spaces. In addition, another limitation was in the hesitation of potential respondents to complete the survey. We received communications via the survey that respondents were hesitant to provide information pertaining to cultural beliefs, knowledge of their communities' TK and opinions on the usage of TK in non-Indigenous spaces.

There was a notable imbalance in gender diversity of respondents which may be attributed to a variety of reasons such as low number of Indigenous males entering the geosciences, or due to the lack of equitable gender identity options available for respondents to select.

Research implications

While there is great diversity within Indigenous populations who have distinctive practices, protocols and languages, there is a commonality as well. The way in which Indigenous communities have a relational approach to interacting and caring for the environment as in giving beinghood to all things, and in the development, analysis, and archiving of extensive and relevant knowledge systems. In order to provide equitable educational opportunities for all students, improve critical thinking skills of students, faculty, and researchers, and to increase innovation, productivity, and problem solving it is imperative that education systems acknowledge more than just Western knowledge systems. It is our hope that geoscience educators gain an understanding of the importance of providing and receiving an equitable education for all of their students and gain an appreciation of the vast knowledge within TK systems. The pursuit of education is driven by curiosity, and we hope to encourage educators to begin a learning journey with their students by incorporating TK systems into their geoscience courses and by establishing meaningful relationships with local cultural practitioners.

Educators can take a first step by simply acknowledging that there are other knowledge systems, more than one way of viewing and interacting with the world, by acknowledging the cultural history of place and the impacts of peoples on place. As courses and departments begin to operationalize recommendations for increasing Indigenous educators and/or mentors, adding TK to courses, and acknowledging history of place, retention of diverse students will increase as science departments become a welcoming and affirming space.

Conclusions

While the barriers are extensive and will take time to broadly overcome, there are immediate actions that educators and researchers can take to effect change in not only the geosciences but all field-based sciences. Acknowledging the extensive history and cultural connections of Indigenous communities to research field sites would have profound implications on all students. This most basic act can make all the difference in the experiences of an Indigenous student and provides rich historical context for research sites. Reimagining how to engage students in field research will broaden participation, retain students from diverse cultures, increase gender balance, and advance the field through innovative research methodologies and practices. The "this is how it has always been done" narratives must be shed as science is not static but ever changing and is based on the foundation of discovery which is accomplished through applying novel approaches to education, research, problem solving, innovation, and forward-thinking scholars. So too should our approaches to providing opportunities for all scholars regardless of race, ethnicity, religion, gender, sexual orientation, and ability. This reimagined model would consider alternative field experiences such as providing opportunities for students during the academic year and a mixed methods approach of providing local and regional field experiences, virtual experiences, data collection and analysis, lab experiences, diverse role models and cultural practitioners, and research into history of place providing cultural context for research sites. Operationalizing recommendations of this study will allow science departments to better understand how to effect change in the geosciences by providing a welcoming and affirming space for Indigenous scholars. Findings of this study provide an understanding of the negative effects of collapsing Indigenous cultures, traditions, and languages into a single identity when trying to design a "one size fits all" approach to recruitment and retention programs, which can also elicit dismissive attitudes, mental fatigue, and feelings of isolation, shame, frustration, and anger (Bressan, 2017; Smythe et al., 2020). The vast difference expressed between respondents who had been mentored by an Indigenous role model and those who had not demonstrates the positive and strong impact relatable role models have on students, their retention, and a fundamental shift in the student's STEM identity.

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