TRIBAL COLLEGE STUDENT PERSPECTIVES:

SUSTAINABILITY EDUCATION CURRICULUM IN STEM

by

Liliana E. Caughman

A Thesis
Submitted in partial fulfillment
of the requirements for the degree
Master of Environmental Studies
The Evergreen State College
June 2017

This Thesis for the Master of Environmental Studies Degree

by

Liliana Caughman

has been approved for

The Evergreen State College

by

Kevin Francis, PhD
Member of the Faculty

Date

ABSTRACT

Tribal College Student Perspectives:
Sustainability Education Curriculum in STEM

by
Liliana Caughman

Native American students have low participation in Science, Technology, Engineering, and Math (STEM). Having STEM skills is vital for society, and is especially important for Native American communities that participate in natural resource management. Thus, the STEM achievement gap must be closed. This research explores the impacts of implementing a Sustainability Education (SE) pedagogy in science courses at a tribal college. Using pre- and post- surveys as well as phenomenographic interviews this work aims to understand student attitudes towards the combined science and sustainability curriculum. Results indicate that students are receptive to this class structure and that they have a positive experience in sustainability focused science courses. Additionally, the SE science courses positively impacted students' science identities, which has been shown to contribute to persistence in science. Tribal colleges and universities can use this work to better understand what leads to student success in science and update pedagogies to better meet the needs of tribal college students in STEM.

Contents

List of Figures

List of Tables

Acknowledgements

First and foremost, I would like to thank my students, peers, and coworkers at the Northwest Indian College Nisqually Campus. They have been extremely welcoming to me and have truly become my second family throughout my time in MES. Also, I cannot thank them enough for participating in my study and allowing me to be creative and implement a sustainability focused curriculum in my science classes. I have unconditional love for every person at NWIC Nisqually.

I would also like to thank the Sustainability in Prisons Project for their flexibility, love, and support throughout my graduate career. SPP was my lifeline at Evergreen and provided me with innumerous opportunities for personal and professional growth. Although this thesis is not focus on my SPP work, the foundation of this thesis came from the great work being done at SPP and their constant effort to create equitable and just environmental education programs.

Additionally, without the guidance and grace of Jean MacGregor this thesis would have never been possible. Jean personally helped me define my own understanding of environmental sustainability pedagogy and provided me with the resources and skills necessary to actually apply it in the classroom. Jean has been an incredible mentor and I cannot thank her enough.

Finally, I must thank my thesis reader Kevin Francis for his cleverness, wit, and problem solving skills. He pushed me to improve the professional quality of my writing and research, which I believe has helped prepare me for PhD work. I also could not have made it through MES without the one and only Emily Passarelli, my most kind and giving friend, as well as Yonit and Sadie in my peer review group. Lastly, this list would not be complete without thanking my loving spouse Megan for being a great listener and my number one fan.

Cheers!

Introduction

Native Americans play an enormous role in natural resource management (Jastad, McAvoy & McDonald, 1996). In the Pacific Northwest, tribes manage large swaths of land and work to sustainably maintain everything from salmon populations and old growth forests to estuaries, prairies, freshwater resources, and more (Charnley, Fischer & Jones, 2007). Every one of these endeavors requires serious science skills. Additionally, several tribes are aiming for complete sovereignty and thus need their own people to fill science-focused positions and pursue related careers within tribal governments (Whyte, 2013). Currently there is a shortage of scientifically trained and educated tribal members to fill these positions and often tribes must hire outsiders for support. To combat this trend, many tribes are making higher education a priority (Tinant et al, 2014). They see the benefit of having a scientifically literate community and believe it can strengthen both current and future generations, especially in a rapidly changing world.

Tribal Colleges and Universities (TCUs) primarily serve Native American or Indigenous students and are often located on sovereign tribal land. Unfortunately, these students exemplify a group that is one of the most underrepresented in the sciences. Students, especially students who have intersectional characteristics, like those who identify as a person of color, female, poor, and disabled -- simultaneously, are some of the most likely to struggle in STEM classes and avoid STEM careers (NSF, 2015). However, these students have limitless potential and deserve the chance to positively engage in the sciences and build their confidence. When successful STEM courses are implemented, more students seek out STEM classes, build their analytical skills, and open their minds to pursing science related jobs (Maltese and Tai, 2011).

Many tribal students enter class with deep admiration for the natural world and their cultural heritage but fail to see the connection between those values and the material they learn in science classes (Oatman, 2015). Hence, by implementing an interdisciplinary sustainability education model that includes these topics within standard Science, Technology, Engineering, and Math (STEM) courses there is an opportunity to tap into the students' interests and desires and hopefully allow them to better engage with science material. Additionally, by allowing students to participate in discourse around environmental sustainability, the sustainability movement can gain the vital perspectives of an often-excluded group of people.

To understand if integrating the sustainability education model into STEM courses does in fact produce these outcomes, we must investigate the following question: *What are tribal college students' perspectives on learning science through topics in sustainability?* This research aims to decipher this inquiry by exploring the students' experiences in an integrated science and sustainability course, investigating how they conceptualize both science and sustainability, and discovering how they see their ability to participate in both disciplines. This will be achieved by: 1) surveying students on their attitudes towards science and the environment before and after their participation in an integrated science and sustainability course, and 2) conducting in-depth interviews with students at the completion of their course.

If the results of this study are positive and show that the tribal college students are receptive to this type of hybrid science and sustainability curriculum, then perhaps more Tribal Colleges and Universities and can adopt this pedagogy. In doing so, there is the opportunity to propel more Native learners to succeed in science and fill vital environmental science and natural resources positions on their land and beyond.

More broadly, the sustainability curriculum could help reshape STEM in higher education so that it becomes more relevant for modern times, and potentially evolve to better meets of needs of other historically underrepresented students. For instance, to overcome the complex issues of climate change we need a society of competent thinkers and radically creative problem solvers who can understand complex interdisciplinary concerns (Gray, 2014). Utilizing a sustainability education curriculum in science requires teaching interdisciplinary concepts using novel methods like research-based projects, mentoring, and learning communities, which have been shown to promote deeper thinking skills (Zoller, 2015). Perhaps this curricular transformation in the college STEM classroom would help to form scientists who can solve broad problem and collaborate across disciplines.

Additionally, by making a shift towards a sustainability curriculum in science it could not only benefit Native American students, but others who have been excluded like women, people of color, people with disabilities, and those from underrepresented backgrounds. Many of the pedagogical approaches prescribed by the sustainability education model have been shown to create an advantageous learning environment for an extensive spectrum of students. Therefore, if this research shows positive results, the sustainability education approach should be applied and evaluated in other institutions of higher learning.

The following chapters will explore the complex nature of creating inclusive and equitable STEM education, the highlights of the sustainability education model, and the specific needs of Native American learners in science. The background section discusses the sustainability education model tested in this thesis, as well as the importance of STEM education, equity, and inclusion. Additionally, it provides a brief historical context upon which to understand Native American's relationship with Anglo education. This will deliver a solid foundation for the literature review and allow the reader to better interpret the results of this work. The literature review covers the important theoretical framework for this thesis including the specifics of building science identity and the types of STEM pedagogies that provide successful learning opportunities for underrepresented minority students and specifically Native Americans.

Finally, the methodology chapter dives into the specifics of research design and analysis techniques conducted in this project. In the results chapter, the analysis of student surveys and interviews are presented. Findings on science identity traits and student opinions on the sustainability curriculum in STEM classes are thoroughly reported. These discoveries are summarized, thoroughly evaluated, and connected back to the literature in the discussion chapter. At the end, the conclusion chapter will look back upon the entirety of the thesis and look forward to how the results can be applied in the future.

Background

Before commenting further on Native Americans in academia and professing that a shift towards Sustainability Education should be made to better meet their needs, it is imperative to understand the context of the current situation. This section provides that context by briefly exploring the history of Native American's traumatic experiences in colonized schools, and the current barriers they face as an underrepresented minority in both higher education and the sustainability movement. This exploration uncovers a need for change within STEM education and the importance of equity and inclusion to both STEM and environmental sustainability. Through the investigation, it becomes even more clear that a STEM education revolution is required to meet the needs of our country and that now is the time to make necessary changes. Finally, the Sustainability Education (SE) model is introduced as a potential avenue for this change. Details about the proposed curriculum are highlighted and the reader becomes ready for a deeper consideration of teaching and learning in the Literature Review chapter.

Historical Context: Native American Education

It is no accident that Native Americans, and particularly Native women, are significantly underrepresented in the sciences. The systematic European colonization, Christianization, and subjugation of American indigenous people have led to the absence of Native Americans in science today. By means of attacking cultural identity, and enforcing a westernized society and educational system, Native Americans were strategically disempowered and their communities continue to feel the effects of this trauma (Guerro, 2003; Tsosie 2010). This history must be considered when tackling the paucity of Native Americans within the scientific community.

Indigenous groups have faced brutal treatment through colonization and implementation of rules that marginalize their culture and force a dominant, usually Anglo, society upon them. In particular, native science and traditional ways of knowing have been pushed aside and do not fit into the mainstream views of Western Science (Smith, 2000). When it comes to increasing participation of Native Americans in science, this is especially relevant, however, the National Science Foundation tends not to acknowledge how indigenous people were forced into their current dilemma. Often, modern problems like poverty or learning differences are used as the basis for understanding the current dearth of Native Americans in STEM. However, negating history does not allow the current problems to be fully understood, and therefore solved. We must acknowledge how detrimental colonization and westernization was to the Native American population regarding their education.

Euro-Americans began the process of “refining” Native peoples and attempting to eradicate their “sinful” cultural practices through missionary boarding schools. These schools were created to immerse young Native Americans in European culture and religion and to educate them according to the United States Bureau of Indian Affairs (BIA) standards. This meant dressing in European wear, speaking English, learning European gender norms, and being stripped away from cultural and traditional values, all while being indoctrinated into the Christian faith. Typically, children were forcibly removed from their families and taken to the schools without any choice; many young students experienced sexual, physical, and/or emotional abuse during their time at boarding school (Emberly, 2010). The trauma inflicted by the US driven removal of Indian children caused “dysfunctional family relationships and patterns such as substance abuse, domestic violence, and sexual abuse, which are still present in many Native families and communities," (Tsosie, 2010). These painful scholastic experiences continue to haunt; it is no wonder that a distrust of western education has formed in some indigenous communities (Smith, 2000).

Beyond personal traumas, there has been ongoing "hostility" towards and often an outright dismissal of indigenous traditional knowledge in the science classroom (Smith, 2000). This was true in the past at boarding schools, and continues to be true today in modern K-12 and Higher Education. As Patricia Hilden and Leece Lee (2010) remark in the book *Indigenous Women and Feminism*,

> "Anyone examining a map of the university's intellectual world will see immediately who belongs and who does not… we learn that only Western-produced knowledge is real, that our stories, dances, arts, and languages are not real repositories of scholarly knowledge but rather myths and legends."

For example, when learning about plate tectonics in an earth science class, a native student in the Pacific Northwest may bring up the traditional story of the Thunderbird and the Whale. In this story, the mythical Thunderbird and the whale are in a constant struggle. When the Thunderbird lifts the whale from the sea the ocean recedes, when the whale crashes back down it shakes the earth and produces huge waves. This is not something one would find in a standard science textbook and could easily be dismissed in the classroom. However, there is real scientific and educational value in this story. Earthquakes in the region often originate from a major offshore fault line and can produce large tsunamis and earthquakes. The tectonic plates, just like the whale in the story, cause movement in the earth and displacement in the water resulting in massive shaking and waves. When a student offers a story like then within the classroom but is instead shut down it can damage their confidence in the science and cause a divide between their culture and their learning.

Western Science has no real way to deal with other knowledge systems since it is highly disciplinary and views itself as an outside observer searching for ultimate truth (Smith, 2000). It may seem that the Native view of science and the Western view of science are at odds with one another, however "Native science conforms in many ways to the definition of Western science" (Cajete, 2000) For instance, both Native and Western science aim to explain natural phenomena in the world and provide information about these phenomena in culturally appropriate and understandable ways. The biggest difference between the two approaches is that in the Native tradition "it is not possible to separate science from ethics, spirituality, metaphysics, ceremony, and social order" (Cajete, 2000). While this is usually looked down upon by conventional science standards, and these topics are rarely included in STEM curricula, I believe this shows that Native Science is not less than Western Science, but more. By integrating components of Native Science into the classroom we could not only begin to ease cultural oppression, but enhance science education by providing enriching learning opportunities for all students.

Finally, current tribes are part of the modern world and would like to be involved in science for a variety of practical reasons including resource management and economic development; however, they need science to be on their own terms (Smith, 2000; Cajete, 2000). Smith says it best, in the book *Decolonizing Methodologies* (1999):

> "Although our communities have a critical perspective of universities and what they represent, at the same time these same communities want their members to gain Western educations and high-level qualifications. But they do not want this to be achieved at the cost of destroying people's indigenous identities, their languages, values and practices."

When this occurs appropriately, Native students are more successful and gain self-esteem (Kawagley, 1994; Martin, 1995). If these types of changes can be implemented on a large, structural scale, then it is likely more Native students will persist in STEM.

STEM Education

In the United States, Science, Technology, Engineering, and Math (STEM) education has come to the forefront of national education priorities and is ripe for reform. A large portion of job growth in the 21st century will take place in STEM related fields and the US aims to have a citizenry that is educated and ready to fill those positions. In the early 20th century the US was a global leader in STEM, however, recent studies have shown that the US now lags behind other countries in areas of math and science literacy (Kuenzi, 2008). According to the Congressional Research Service, "In a recent international assessment of 15-year-old students, the U.S. ranked 28th in math literacy and 24th in science literacy. Moreover, the U.S. ranks 20th among all nations in the proportion of 24-year-olds who earn degrees in natural science or engineering," (Kuenzi, 2008). This shows just how far the US has fallen behind other modern countries in preparing students for a scientific future.

Therefore, STEM education and literacy have emerged as significant targets of the US Department of Education, the National Science Foundation (NSF), the National

Institute of Health (NIH), and the Department of Energy (Kuenzi, 2008). In fact, in 2011 the National Science and Technology Council (NSTC) created a committee of Science, Technology, Engineering, and Math Education (CoSTEM), which aims to coordinate federal programs in support of STEM education (Sargent and Shea, 2012). The US government believes STEM literacy is essential for American success in the future and it is funneling resources into higher education to support the cause. This shows that there is an opportunity to reinvent STEM education and evolve it to better meet the needs of diverse students in the context of global challenges.

Equity and Inclusion

According to recent Census Bureau projections, minorities will account for 57% of the U.S. population by 2060 (Hobbs and Stoops, 2002). Since the job market for STEM fields is growing rapidly and there is a need for a generation of analytical problem solvers, people from across diverse social and ethnic categories must become involved in STEM. However, STEM fields in the US are largely homogeneous, dominated by White and Asian men (NSF, 2015). Generally, "the representation of certain groups of people in science and engineering (S&E) education and employment differs from their representation in the U.S. population," (NSF, 2015). Specifically, three ethnic groups (Blacks, Hispanics, and American Indians), as well as women, and people with disabilities are considered to be underrepresented minorities (URMs) in STEM (NSF, 2015). This is a major problem both for educational justice and for the advancement of human knowledge and technology. Diverse groups contain varying perspectives and voices to overcome tough issues, homogeneous groups on the other hand do not breed as much “creativity and effectiveness while solving problems” (Oyana, 2015). To have an effective and equitable STEM workforce the representation gap in STEM must be closed.

There has been a great deal of time and energy dedicated to increasing diversity in STEM; the issue has risen to become a national priority attached to overall STEM education and literacy. In fact, there is a biennial report produced, mandated by the Science and Engineering Equal Opportunities Act (Public Law 96-516), titled *Women, Minorities, and Persons with Disabilities in Science and Engineering* that looks at participation of various groups in STEM across higher education. The findings of this report show that while some incremental improvements to diversity in STEM have occurred over time, large strides in amassed diversity have yet to be observed. Researchers are investigating the reasons behind this trend and practitioners are attempting to reverse it. The hope is that by understanding the factors that contribute to URMs recruitment, retention, and success in STEM fields the climate of STEM can evolve to better solicit URM participation and achievement.

Concerns about equity in STEM mirror similar discussions within environmentalism; contributors must be representative of the global community. When combatting current and future environmental issues, including global climate change and accompanying social justice issues, it is imperative to include viewpoints from a wide range of stakeholders. Climate change reflects the collective power of humanity and it will take a broadminded global society to solve the complex problems we now are facing. This fact demands that all people have access to education and resources that can allow them to reach their highest potential, not only for individual fairness, but also for the greater good of life on our planet.

In the past, some of the largest criticisms of environmentalism have focused on the race and class privilege of many of its proponents and endeavors. Critics have challenged the values and vision of western environmentalism as catering to a predominately white and colonial viewpoint (Adam and Mulligan, 2003**).** Fortunately, the field of Environmental Justice (EJ) rose in response to environmental racism and the systemic exclusion of people of color and others from less privileged backgrounds from standard environmentalism. Through activism, lawsuits, and legislation, EJ has added a dialogue of anti-oppression and a social justice orientation to the modern definition of environmentalism. EJ focuses on the "fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (EPA, 2016). While EJ has come a long way, there are still many battles ahead, including most recently a focus on Climate Justice. Taking EJ into consideration shows how environmental sustainability work is not separate from issues of social justice and equity, but innately connected to them. Therefore, sustainability and environmentalism must aim for solutions that are equitable for all people and include all people in the process.

In both STEM and the environmental sustainability movement, topics of diversity, inclusion, and generally equal access for all people have become a worthy priority. However, there is still a great deal of work to be done to make full equity a reality in either discipline. Again it is clear that now is the time for changes that support and create this progress.

Sustainability Education

Introducing sustainability topics and classes into conventional school settings is one of the emerging strategies being considered to move status quo educational practices in a new direction. Since the early 1990s there has been growing interest in developing sustainability focused pedagogies for use in higher education (Tilbury, 1995). This type of Sustainability Education (SE) can be applied in a plethora of ways and take many forms. The model is flexible and adaptable for use in a variety of classes and circumstances and shifts depending on the goals of the educator using it. This keeps course topics and practices relevant and malleable, which is one of the strengths of implementing Sustainability Education (SE) in a modern classroom. This research aims to evaluate the impacts of employing an SE curriculum in STEM classes at a tribal college, in hopes it can create a more advantageous learning environment for Native students.

Since there are so many ways to apply Sustainability Education, it is impossible to test a version of the curriculum without defining its specific parameters. For the purposes of this research, Sustainability Education (SE) will be understood as *an interdisciplinary educational model, which appropriately prepares students for an uncertain future in the context of global climate change*. Although there is no official consensus among sustainability educators, some version of this definition generally appears in nearly every study of applied Sustainability Education (SE) (O'Byrne, Dripps, & NIholas, 2015; Wright and Horst, 2013; Wals, 2014).

To create not only a workable definition, but a usable model, the parameters of curriculum design, content development, classroom application, and assessment of learning outcomes commonly used in SE must be specified[1]. The version of SE implemented in this study draws on modern research and includes a shift in educational pedagogy comprising of: 1) development of Higher Order Cognitive Skills (HOCS) by means of problem solving and critical thinking as opposed to rote memorization and algorithms (Zoller, 2015); 2) integrated, interdisciplinary classes combining topics of science, technology, environment, society, policy, sustainability, etc. as opposed purely disciplinary subjects i.e. math, physics, geography, political science, etc. (Coops et al, 2015; Ward et al, 2016). 3) experiential and applied learning opportunities including the use of learning communities, community based research, mentoring, and dissemination as opposed to purely lecture and examination (McPherson et al, 2016; Wilson and Pretorius, 2017), and 4) a strong interwoven focus on the environment and social justice, predominantly scientific and social aspects of climate change, and related global and local environmental issues (Drolet, Taylor, and Dennehy, 2015; Wiek et al, 2014).

Implementing the SE model within STEM classrooms might just be the change that STEM needs, and this thesis puts it to the test. The SE curriculum may be beneficial to Native American students as well as other URMs and would introduce topics of environmental sustainability to a diverse set of people who may in turn become involved in the environmental sustainability movement themselves. This could have enormous impacts for Native American learners and their communities, while more broadly increasing inclusion and diversity in both environmental sustainability and STEM education across the country.

[1] For more details on how aspects of SE have been applied in other contexts see the Literature Review chapter. For more details on the exact curriculum used for this research see the Methodology section.

Literature Review

Introduction

This section synopsizes research explaining why some groups are underrepresented in the sciences and the pedagogical approaches can be taken to improve student success. It examines the strategy of using a science identity framework to create STEM curricula that works for all students. For one to be successful in STEM, the culture of these disciplines must somehow align with the identity and motivation of the individual. For many underrepresented minority students (URMs) STEM fields do not tend to offer this type of personal connection or relevancy. This can be particularly detrimental for Native American students, for whom connection to place, traditions, and community are of utmost importance. Despite these difficulties, some URM students continue in science, and some teachers have found methods that work. Ample research has gone into identifying the contributing factors. Although there are many overlapping reasons that cause Native Americans, women, and other URMs to either persist or fail to persist in STEM, some of the most important are the development of a science identity, a connection to practical and socially applicable research, and experiential and community building opportunities like mentoring and research projects. For Native students in particular this means implementing culturally relevant science content and learning activities that sustain a deep connection to place.

Science Identity

The development of a science identity, the psychological process of one being inspired by STEM to the point of personal relevance, ownership, and integration into the sense of self is one of the leading factors of success in STEM. Growing research since

2000 supports the importance of science identity to STEM success. Brickhouse, Lowery, and Schultz were some of the first to study, as they described it "how students are engaging in science and how this is related to who they think they are," rather than simply what science facts they know (2000). Utilizing four case studies, each focusing on a middle school aged, black, female student who self-identified as interested in science, the researchers thoroughly explored and compared the identities of each student. Results showed that the girl's identities interacted with school science identities and that this interaction played a role in their scholastic experience. The conclusion of this paper called for further research into science identity and how it correlates to academic achievement in the sciences. Since then, using a science identity based framework to understand URM persistence in science has proven to be a robust and trusted method (Hazari et al., 2010).

In 2007, Carlone and Johnson undertook a longitudinal study aimed at understanding the experiences of successful women of color in STEM fields to gauge why some women were exiting the science pipeline. This study tracked 15 successful women of color throughout their undergraduate, graduate, and science-related careers. By conducting ethnographic interviews, they found that racial, ethnic, and gender identities fed into academic performance, recognition, and competence to create each individual's science identity. This placed the women into three distinct science identity groups: 1) research scientists who were "passionate about science and recognized themselves and were recognized by science faculty as science people", 2) altruistic scientists who "regarded science as a vehicle for altruism and created innovative meanings of 'science,' 'recognition by others,' and 'woman of color in science'", and 3) disrupted scientists who “sought, but did not often receive, recognition by meaningful scientific others,” (Carlone and Johnson, 2007). Although they were ultimately successful, the trajectories of the disrupted scientists were “more difficult because, in part, their bids for recognition were disrupted by the interaction with gendered, ethnic, and racial factors,” (Carlone and Johnson, 2007). What differentiated the experiences of these women of color was in how they were or were not recognized as “science people” by others.

It has been shown that when students can see themselves as “science people” they are more likely to pursue and be successful in the sciences during college and beyond. One example of this can be seen in a 2013 study which explored science identity and its connection to intersectional issues of gender, race, and ethnicity (Hazari, Sadler, and Sonnert). This research sought to understand what it means to be a “science person”. In the study, survey data from 7,505 college students who participated in the Persistence Research in Science and Engineering (PRiSE) project were analyzed. In particular, the researchers were interested in how students responded to the question “Do you see yourself as a biology/chemistry/physics person?” Their findings indicate that overall URMs rank themselves lower than their male, white, and Asian counterparts (Hazari et al, 2013). Additionally, this research shows that those with reduced science identity are less inclined to pursue majors or careers in the sciences. These results support other previous research in the arena and indicate that with greater science identity students may be more likely to continue in science.

Since science identity has come to the forefront of engaging URMs in STEM, researchers have turned to studying curriculum, pedagogies, and programs that may positively impact student’s science identity. One such study investigates the effectiveness of “scientist spotlight homework assignments” to enhance student’s science identity in a science courses at a diverse community college (Schinske et al, 2016). The goal of these assignments was to broaden the image of a scientist and thus allow the students to identify with what it means to be a scientist or science person. Each week students read academic work done by a unique scientist and were exposed to the scientist’s background story. Using a pre/post method that analyzed essays written by the students at the beginning and then the conclusion of the course, they found that the scientist spotlight assignments were successful at broadening the student’s view of scientists and aiding development of science identity (Schinske et al, 2016). Furthermore, longitudinal data showed the effects of the assignments were still present six months after the conclusion of the course and that there is a positive correlation between study participation, interest in science, and science grades. This research goes to show that even minor changes in curriculum or creative tweaks to classroom assignments can have large and lasting positive impacts on students, their science identity, and success in STEM.

STEM Pedagogies for URM Success

A positive science identity can lead URM students to success in STEM, but sometimes considering an abstract idea like ‘identity’ can be excessively theoretical and fail to provide practical solutions. Therefore, many studies focus not on building science identity directly, but on evaluating applied strategies and practices and their ability to support and retain diverse students. These studies investigate programs, classes, curricula, and pedagogies, and analyze their ability to positively impact URM students in STEM. It has been shown that when college level STEM prioritizes pro-social motivation, practical and socially applicable research, and provides experiential or community-building learning opportunities, URM students are more inclined not only to persist, but to thrive. This research purports that these pedagogical approaches are successful because of their ability to engage students and simultaneously cultivate their science identities.

Philanthropic motivation and the building of science identity are interconnected. Of interest for this analysis is the altruistic scientist identity, or those who decided to be scientists in order make the world a better place. These women found success by creatively defining the purpose of science in their own terms and persevered because of charitable motivations – they felt connected to science because they saw science as a means of helping others, improving the world, and creating change (Carlone and Johnson, 2007).

Indeed, this type of pro-social motivating factor has been documented in other studies as well (Estrada et al, 2016). For example, women recently surpassed men in their representation in biological fields (psychology, social science, and life science). Some research has asserted that women can better connect to the positive social outcomes of biological scientific research, which may be contributing to this phenomenon. For instance, in a 2012 study on "Gender Segregation in Elite Academic Science" over 2000 scientists from 100 departments at 30 universities were surveyed and 216 were selected for in-depth interviews where they were asked about their perceptions of the gender gap in different scientific fields (Ecklund, Lincoln, and Tansey, 2012). Both the survey and interviews yielded a few common themes, with one of the most often cited reasons being "natural differences", both biological and cultural, between men and women (Ecklund et al, 2012). Women tended to ascribe these differences to "reasons of emotional affinity" and described biology as more practical and concrete than theoretical fields like physics

(Ecklund et al, 2012). One physicist even said that due to the social benefits she would rather have cancer research funded than her own work in physics (Ecklund et al, 2012). This shows that the emotional lure of biological sciences is strong, even in some women who have chosen to work in the physical sciences.

Furthermore, several studies have shown that not only many women highly value the social impacts of their scientific work, but so too do many underrepresented minority (URM) students (Hurtado et al, 2010). Research that surveyed over 26,000 college students from 160 universities, compiled by the UCLA Higher Education Research Unit, found that “URM students often leave the sciences due to the perceived lack of social value or relevance to improving conditions for their communities,” (Hurtado et al, 2010). While perceived lack of social value causes students to leave the scientific pipeline, connecting class lessons directly to the values of the students has been shown to have positive impacts on academic success and persistence in the sciences (Harackiewicz et al., 2013). Socio-emotional value in scientific research and education is vital for the participation of URMs in STEM. Perhaps, since it is important for the students' “scientific labor to have a practical application that benefits society,” scientific disciplines should take note and markedly introduce the potential social benefits of their research to young students as they enter the field (Ecklund et al, 2012). This can be achieved by something as simple as having students do writing activities that connect STEM topics to their own lives (Hulleman et al., 2010). Therefore, taking measures to highlight the social importance of STEM could aid the recruitment and retention of women and URMs in science.

Besides STEM content being practical and socially applicable, it is beneficial for women and URMs if the academic environment provides experiential learning activities that aid community building. A few examples include mentoring, learning communities, and research experiences.

Mentoring, by more advanced scientific peers, upperclassmen, graduate students, postdocs, professors, or professionals has proven to be one of the biggest indicators of success for women and URMs in STEM (Carlone and Johnson, 2007; Cole, 2008; Ecklund, 2012; Herrman et al, 2016; Hurtado et al, 2010). One reason for the importance of mentoring, as documented by Hurtado et al (2010), is that having guidance and feedback from faculty members and peers aids the development of a science identity. Students can receive feedback and praise from trusted authorities, which can lead them on their own path towards success.

In addition, mentors act as role models, which can be especially effective if the role model is the same gender or ethnicity as the student (Ecklund, 2012). It has been shown that when students simply receive even small amounts of outreach from a mentor, in the form of a letter or email, where the role model “normalizes concerns about belonging and emphasizes the value of a college degree” it can greatly impact student grades and motivation to stay in STEM (Herrman et al, 2016). Students with mentors can actively engage with these role models and picture themselves as successful scientists in their discipline who are part of the scientific community (Ecklund, 2012). Furthermore, in a study on factors that contribute to persistence and success of Latino students in STEM fields, it was found that there is a strong positive correlation between “faculty support and encouragement” and the strength of a student’s GPA (Cole, 2008).

Additionally, if students do not have mentors, or have a negative experience with a mentor, their science identity can be negatively impacted and their chances of success hindered (Carlone and Johnson, 2007). Therefore, the role of positive mentoring is of upmost importance for women and URMs in STEM fields.

Mentors offer support and encouragement to URM students in the sciences, but that needed support can also come from other sources like peer groups and learning communities. Learning communities, or spaces where groups of people can collaborate on classwork and work towards shared academic goals, have also proven to be an integral instrument for supporting URMs and women in STEM (Dagley et al, 2015; Dennis et al, 2005; Hurtado, 2010). For example, students increased their chances of persisting in STEM by more than 150% if they joined a pre-professional or departmental club in their first year of college (Hurtado, 2010). It is thought that such learning communities aid student success by developing their science identity and allowing students to form bonds with a peer group that shares academic and career goals, motivating students to work together to succeed (Hurtado, 2010). Additionally, this peer network can work to provide support for academic achievement including formation of study groups, sharing knowledge and experience, and advising about which classes to take or research to pursue (Dennis et al, 2005). A prime example of a successful learning community can be seen in the University of Central Florida's STEM EXCEL program. Each year 200 first year STEM majors join the learning community that has both social and scholastic components (Dagley et al, 2015). Students involved in EXCEL have a 43% higher retention rate, and URM students have much higher graduation rates compared to similar students not involve in the learning community (Dagley et al, 2015). When students bond together, they feel a sense of community, they can see themselves in the struggles and successes of their peers, and they can cultivate their science identity.

While substantial research shows the positive impacts of such learning communities, it is important to note that Cole (2008) found a negative correlation between involvement in co-curricular activities/group studying and GPA of Latino STEM students. This does not mean that these activities necessarily cause a lower GPA, but could indicate less time spent "on-task" and deeply focusing on schoolwork (Cole, 2008). From this it follows that the type and quality of the learning community must be appropriate and resonate with the desired college learning outcomes to be effective. However, if properly crafted, like the EXCEL learning community in Florida, learning communities can act to bring students together and build strong academic bonds, further connecting women and URMs to science.

Undergraduate research opportunities (UROs) often offer students a combination of learning communities, mentorship, and hands-on research. UROs have proven to be essential for the success of all students in STEM, but are particularly important for women and URMs since they build science identity and increase motivation (Ghee et al, 2016; Hurtado, 2008; Russel et al, 2007). Hurtado (2008) found that for minority students "participating in undergraduate science research opportunities through structured programs appears to contribute to persistence and the development of an identity as a scientific researcher." Additionally, in their study of successful women of color in STEM, Carlone and Johnson found that almost every woman they interviewed had participated in undergraduate research (2007). On the one hand, the women who developed the most rigorous research scientist identity had partaken in the most positive research experiences where they were included as authors on publications and presented their work at conferences (Carlone and Johnson, 2007). On the other hand, some of those with the disrupted science identity had negative research experiences, plagued with gender discrimination or lack of recognition (Carlone and Johnson, 2007). For better or worse, this shows just how vital such research opportunities can be in developing science identities and motivation to continue into a research-oriented career in academia.

Participation in a successful URO strongly impacts student's interest in pursuing STEM related careers and graduate studies (Russel et al, 2007). This data, from a survey of 4500 undergraduates and 3600 faculty, graduate students, and postdoc mentors who participated in NSF sponsored UROs also found that "among racial/ethnic groups, effects of UROs tended to be strongest among Hispanics/Latinos and weakest among non-Hispanic whites," (Russel et al, 2007). Research experiences give STEM students the best look into their future as academics and can be the turning point in many young scientists' careers.

There are many ways to broaden participation in undergraduate research and the impacts can last well into a student's career. For example, by simply adding research components to introductory level science courses, institutions can potentially impact a wide variety of URM students and influence their choices to remain in science. For instance, Harvey Mudd College in Claremont, California recently updated the curriculum for their introductory level computer science courses, adding a research and professional development component. They saw the number of women in their computer science program grow from 10 to 40% in only five years' time (Corbett and Hill, 2015). Additionally, it has been shown that research experiences work to illuminate possible careers within STEM fields and simultaneously motivate students to pursue those endeavors (Ghee, 2016; Lopatto, 2007). Ghee et al. (2016) surveyed students before and after the completion of a summer research program for undergraduates. They found that before the program 60-70% of students reported understanding the graduate school application process, graduate school life, and careers available in their scientific discipline; by the end of the summer that number jumped to 90% (Ghee et al, 2016). Clearly, if more students can have the opportunity to become involved in undergraduate research then there is a high likelihood of increasing their scientific identity, graduation rates, and ultimately retention in STEM careers.

Overall, a combination of socially motivated work, hands-on experiential learning opportunities, and connection to community may work in tandem to increase URM students' science identities and propel them to success in STEM.

Native American Teaching and Learning

While there is a plethora of studies that focus on Underrepresented Minority students (URMs) in the sciences, fewer focus specifically on the needs of Native American students. Often, studies will group Native learners into the demographic category of "other" which fails to highlight their unique experiences as science students. However, many of the strategies that were emphasized in the previous section are also applicable for Native American students. For instance, Maughan, Bounds, Morales, and Villegas (2001) highlighted the importance of mentors for Native American learners and Oatman (2015) showed the significant role identity plays within the science classroom. In addition, research indicates that interdisciplinary coursework and inquiry-based approaches to learning facilitate Native student success in the sciences (Roehrig et al, 2012). While each of these components contributes to a positive learning experience for Native students, two of the most important aspects necessary for student success are place-based learning and culturally sustaining pedagogy (Kowalczak, 2013; McCart et al, 2014; Oatman, 2015; Riggs 2005; Roehrig et al, 2012; Semken, 2005: Sleeter 2012).

Best practices in science education for Native American students includes the need for place-based curricula. Science classes should offer material that is experiential, connects students to their homeland, and gets students outside studying familiar environments from a scientific lens (Riggs, 2005). Riggs (2005) calls for the "explicit inclusion" of culturally relevant material within science courses, including but not limited to traditional indigenous knowledge and the involvement of tribal community members and elders. This pedagogical approach seems to align with the importance of experiential learning opportunities, socially relevant material, and community focused practices, which were shown to be pertinent for the success of all URM groups within the sciences. The biggest difference between what other URMs require and the specific needs for Native American learners, is the extent to which these practices are important. Connection to place and community runs deep particularly on traditional lands which tribes have lived on for hundreds, if not thousands of years.

In an analysis of Native American students that participated in an outdoor STEM camp, in-depth interviews explored student experiences learning environmental science in a hands-on and culturally significant way (Kowalcak, 2013). The students described how the camp provided culturally related material, which made them feel more deeply connected to their tribe during the scientific learning process (Kowlacaks, 2013). Additionally, students described the hands-on lessons and place-based scientific research opportunities provided to them at the camp as enjoyable, even though most of them had referred to themselves as bad at math or disliking science (Kowlacks, 2013). Results showed the STEM camp influenced the participants' attitudes about themselves in relation to science, and that a place-based and culturally connected curriculum can have a positive influence on students' science identity. As mentioned in previous sections, the growth of a positive science identity is crucial for one's desire and motivation to continue within in the sciences.

Using a place-based and culturally competent curriculum to teach science to Native learners is not only good for their psychology, but works to teach complex science topics. A 2004 study describes the ways in which a science program in the Navajo Nation used the local environment and traditions to teach geoscience content (Semken). The course used the local Plateau to introduce topics of geology, which then evolved into lessons on both climate and environmental quality (Semken, 2004). This allowed for the students to be introduced to fundamental science subjects including plate tectonics, mountain building, magnetism, landscapes, fossils, fossil fuels, volcanism, and groundwater basins in ways associated with their personal lives and the areas in which they live (Semken, 2004). Each of these topics were also connected to the ancestral stories of how each of the geological features came to be, which allowed students to hold both traditional and modern science viewpoints simultaneously. This permits the dissolution of cultural discontinuity between western science and indigenous life, empowering students to engage in science in meaningful ways.

Indeed, when a culturally sustaining pedagogy (CSP) is properly implemented in the classroom it can motivate students by valuing both their identity and cultural expression (Oatman, 2015). Tribal sovereignty, or the recognition that tribes have the right to full self-governance, should be at the core of CSP teachings (McCarty et al, 2014; Oatman, 2015). Material taught in class should be cognizant of colonizing influences and should also make space for the reclamation of Indigenous language and culture (McCarty et al, 2014). Often this means that the course curriculum should engage in community-based research and educational activities, while also offering students the opportunity to critique social issues and institutions surrounding race and inequity (McCarty et al, 2014; Oatman, 2015). In her 2015 dissertation "Culturally Sustaining Pedagogy in a Science Classroom: The Phenomenology of the Pit House" Oatman examined students' experiences in the CSP focused course. Her analysis showed that identity politics and self-efficacy in science were key themes that emerged from the students' involvement (Oatman, 2015). Self-efficacy relates to one's sense of self and the belief that one can succeed in a given task, which is intimately connected to identity. Therefore, by virtue of CSP in the science curriculum, science identity is indeed being impacted.

Despite the best intentions of educators, CSP can be challenging to include in the classroom, and it has generated some criticism when improperly applied (Nykiel-Herbert, 2010; Sleeter, 2012). Research by Sleeter (2012) points to three main condemnations that feature an incorrect interpretation and application of CSP: simplification, trivialization, and substitution of cultural relevancy. For example, to simplify could mean to merely "celebrate" culture in the classroom, which does not fully constitute culturally relevancy and therefore does not foster student success (Nykiel-Herbert, 2010; Sleeter, 2012). Trivilization could indicate an occasional culturally related activity but no further integration, and substitution avoids discussing issues surround racism and oppression in hopes that talking about tolerance is enough (Sleeter, 2012). Instead, cultural relevancy must be fully engrained into the curriculum, it should be utilized as a means for learning, and it must enable students to use their own lives to deepen their scholarship (Nykiel-Herbert, 2010; Sleeter, 2012). In general, it is important for educators not to diminish the culturally focused parts of the curriculum; they must unequivocally and confidently incorporate interdisciplinary topics regarding tradition, community, and the history of colonialism in their courses so that their Native students can triumph.

Conclusions

There must be a paradigm shift within science education to better make space for women and URM learners, and specifically Native Americans. Dull, theoretical, individualistic and sterile STEM courses alienate a diverse set of students and appeal primarily to the status quo scientists: white and Asian men. In order to become more inclusive, science curricula must make a transition towards place-based activities, experiential learning opportunities, culturally sustaining pedagogies, community oriented practices, and generally more socially relevant material.

Thinking back to the description of Sustainability Education (SE), as outlined in the background section of this thesis, it appears that there is overlap between what the sustainability education model prescribes for science curriculum and what Native and other URM students require in order to succeed in STEM. In particular, implementing Sustainability Education in STEM would be a paradigm shift in higher education; it would redefine what it means to study science. This offers a chance to redefine the traits of scientists and could give students new opportunities to imagine themselves as scientists, thus supporting the development of their science identity.

Further, the Sustainability Education in STEM model puts experiential and community-based learning at its core. There is a strong focus on local research experiences for students and learning community activities are made a priority in the classroom. This directly connects to research that has shown how important community involvement and hands-on learning opportunities are to retain Native Americans and other URMs in STEM. It has been well documented that URM students respond better to STEM fields in which the effects of their research can benefit society. Additionally, it has been shown how crucial it is for Native American students to have culturally sustaining classroom material that connects to both tradition and institutional inequities. Yet again, the Sustainability Education (SE) model calls for these interdisciplinary issues to be included within standard science curriculum. Specifically, the model prepares students to face the interdisciplinary issues of the Anthropocene and urges them to find creative solutions to problems like global climate change and local environmental injustice. This focus on a big, interconnected picture could very well inspire students by allowing them to emotionally connect with their work and connect it with their lives.

The connections between the SE model and the needs of Native Americans and other URMs in STEM cannot be overlooked; there is strong potential here to move science into a new direction that is more appropriately structured for a diverse set of students to thrive. Currently, there is no research exploring the potential of the Sustainability Education (SE) pedagogy to engage URMs or Native American students in science. This research aims to uncover if indeed this SE model creates an advantageous learning environment for Native Americans within STEM by means of implementing the pedagogy and interviewing the student participants regarding their experience.

Methodology

The goal of this thesis is to understand if implementing the sustainability model within STEM classes is advantageous for Tribal College students. In order to explore this phenomenon, it is useful to ask: *What are Tribal College students' perspectives on learning science through topics in sustainability?* Therefore, for this study a purposive selection of Tribal College students were surveyed and interviewed regarding their experience participating in a science class that incorporated the sustainability curriculum. The survey results were analyzed quantitatively to describe students' attitudes towards science and sustainability immediately before and after participation in the course, as well as to describe the demographics of the study group. The interviews were transcribed and then coded using a phenomenographic qualitative analysis technique, rooted in the theory of science identity.

Science and Sustainability Courses

The students who participated in this study took either an "Introduction to Biology" or "Introduction to Geology" science course that incorporated the sustainability curriculum model. These quarter-long courses are at the freshman undergraduate level and aimed at students enrolled in Associate Degree programs. Class sizes at this college are small, there were 6 students enrolled in Biology and 8 enrolled in Geology. Both courses are described below:

> *Introduction to Biology:* This class utilized inquiry, problem-based learning, and case study methodology to allow students to directly experience the scientific method, understand the nature of biological systems, and discover how matter and energy work in living systems. It also covered the importance of environmental sustainability in the context of climate change and its impacts on biological systems.
>
> This class was aimed at providing students with hands-on opportunities to learn the scientific method and explore real-world concepts and issues.

Students gained experience in how scientists explore questions through inquiry, problem-solving, and critical thinking. Learning themes included: regulation, structure and function, evolution, community ecology, biological sustainability, and local biological impacts of climate change.

Essential questions covered in the course include: How do scientists use the scientific method to solve problems? How do invasive species affect aquatic systems in the Pacific Northwest? What are keystone and indicator species, and how can they be identified? How does population adaptation and natural selection lead to the evolution? How do climate and environmental factors influence biologic processes? How do we use a decision-making model to make decisions about biological systems?

Introduction to Geology: This class was designed for students to learn, through hands-on inquiry, the nature of earth systems and how matter and energy work in the interior and exterior of the earth. Students worked to develop a positive attitude towards science while understanding what it means to learn scientific concepts. They also became more familiar with the geologic processes associated with climate change and its effects on interconnected earth systems.

Learning themes included explaining and interpreting geologic processes, characterizing and explaining the nature of geologic events that could affect their lives in the Pacific Northwest, interpreting the geologic and environmental processes involved in forming and changing local and global landscapes, and understanding the importance of scientific research and communication, particularly as it relates to environmental issues and sustainability.

Essential questions covered in the course include: How do scientists use the scientific method to solve problems? How do geologic processes contribute to natural disasters in the Pacific Northwest? What is our local geology and how can it be studied? How do river systems connect to the rock cycle, sediment transport, and the health of ecosystems? What are fossil fuels and how are they connected to climate? How do we use a decision-making model to make decisions about geologic systems?

For both courses, each standard life or earth science module was accompanied with a topic and activity that highlighted a connected environmental, social, cultural, or economic sustainability issue. The goal of this was to give meaning to the material in order to draw students in to the courses in a tangible way, while also increasing their sustainability literacy. Some sustainability topics that were paired with biological concepts included: climate change and local affects, benefits and costs of genetically modified organisms, ocean acidification and local shellfish, natural resources and salmon, tribal fishing rights and protections, symbiotic relationships between native plants and native bees, and the microbiology of soil and composting. Some sustainability topics that were paired with geological topics included: No Dakota Access Pipeline/Standing Rock protests and fossil fuels, natural disasters and traditional stories, climate change and tribal investments in renewable energy, local mountain glaciology and global warming, river geomorphology and dam removal, rocks and minerals and global technology economies.

An example of one activity that went particularly well was the water filtration lab. This lab occurred within the "Sustaining Natural Resources" module of the biology course when the class was focused on ecosystems, ecosystem services and bioremediation. The goal was for each student to design and build a water filter using only a cup and a variety of natural materials. This served a dual purpose of showing how naturally occurring biological and physical systems provide us with services, like cleaning our water, while also thinking about sustainable architecture and green building. After the students built their filters we had a class competition to see whose filter worked the best. A disgusting mixture of water, oil, dirt, cigarette butts and ash was poured into each filter and we judged them as a group on drain time and water cleanliness. Then, we analyzed the results as a class and thought critically about what made some filters work better than others. This demonstrates a successful science and sustainability education activity: it offered a remarkable opportunity for hands-on interdisciplinary learning.

When describing these courses it is also important to note that the classes were designed, implemented, and taught by the author of this study, which presents both pros and cons to the study design. While there is the potential that this introduced bias into the students' responses, it is not uncommon for educational research to be undertaken by the educators themselves (Demircioglu, 2008; Oatman, 2015). In fact, especially in close knit communities like this Tribal College campus on a reservation, having the interviews conducted by a well known and trusted educator can illicit more open responses (Roehrig, Campbell, Dalbotten, Varma, 2012). Details describing how potential bias was mitigated will be further discussed in the survey and interview portions of the methodology section.

Student Subjects

Each student enrolled in Biology and Geology was invited to participate in this study, but it was not a required part of the course. In the end, 9 students participated in both the pre and post surveys (5 from biology and 4 from geology) and 10 students participated in interviews (6 from biology and 4 from geology). The following table describes the demographics of the students:

Demographics of Student Participants			
Characteristic	**Category**	**Number of Participants (n)**	**Percent (%)**
Age			
	Under 18	0	0%
	18-24	2	22%
	25-34	3	33%
	35-50	3	33%
	Over 50	1	11%
Race/Ethnicity			
	Native American or Indigenous	9	100%
	Caucasian (mixed)	2	22%
Year in College			
	1 (freshman)	5	56%
	2 (sophomore)	3	33%
	3 (junior)	1	11%
Number of previous college science classes			
	0	4	44%
	1 or 2	4	44%
	3+	1	11%

Table 1. This table shows the self-reported demographics of the students who took part in this study. All students identified as Native American or Indigenous. Most students were early in their college careers and had taken 2 or fewer science courses. Student ages varied widely.

Surveys

The students who were involved in this study were surveyed immediately before and after participation in their science course. The 9 students who chose to participate in this portion of the study took the pre-class survey on the first day of class before instruction began. They then took the post-class survey on the last day of class, directly after instruction concluded. Students were surveyed in this way to best gauge the direct impact of the course on their scientific and environmental interests and engagement. Additionally, the pre-class surveys were useful to get a picture of the viewpoints of the students before the course, since in-depth interviews were only conducted after the course.

The survey instrument consists of 34 questions that were taken from scales developed and verified by the Cornell Citizen Science group at the Center for Ornithology. These tools have been validated and are used by numerous organizations to evaluate scientific and environmental literacy.

Survey data was analyzed using a pre-post method of comparison. This allowed for changes in student attitudes before versus after the course to be described, explored, and quantified. Four areas of the survey were analyzed 1) self-efficacy for learning and doing science, 2) self-efficacy for environmental action, 3) nature relatedness, and 4) interest in science. These sections were chosen from the Cornell Citizen Science guide of evaluation instruments used to measure environmental and scientific literacy. Taken together, the results from these surveys provide a representation of the students' baseline feelings towards science and the environment from both a personal and academic stance. The data were analyzed and interpreted using the methods as outlined on the survey tool scoring instruction guidelines (see Appendix 1). This data can be subject to statistical analysis, but is primarily used descriptively as the sample size for this study is quite small.

There is a potential for bias in this methodology specifically because the researcher is also the classroom instructor and is a part of the close-knit college community. Therefore, some students had a close relationship with the researcher, which may have influenced their responses on the surveys. However, potential bias was mitigated in two main ways: 1) by assuring students that their grades in the course would not be impacted by the results of their survey and 2) by informing them that honest answers would be used to help improve future science courses. Additionally, despite the possible bias, the benefits of having a community member conduct the research far outweigh the costs. Without having a relationship with the school and the students this research would likely have never been approved.

Interviews

Students who were involved in the study were interviewed regarding their experience in the science course within 1 week of completing the class. There were 10 students interviewed overall and each interview session lasted approximately 30 minutes. The interviews were audio recorded and then each recording was manually transcribed.

The goals of the interviews were to: 1) explore students' prior and current perceptions of science and sustainability, 2) explore students' views toward the science lessons contextualized in issues of sustainability, 3) describe the students' views of experiential learning as it relates to the scientific lessons, and 4) describe students' perceptions of their ability to take part in scientific and/or sustainable actions. In general, the aim was to understand at a deep level the individual learning experiences of individual students.

As mentioned above, due to the close relationship between the researcher and the students who participated in the study, there is a slight concern for possible bias. In order to minimize this concern, potential bias was mitigated in a few main ways: 1) students were given a separate time and space to express grievances and/or admiration for the course as well as to provide feedback on the quality of the teaching, 2) students were told they were not being tested, there are no right or wrong answers, and responses would not impact their grades, and 3) students were informed that honest answers would be more useful in understanding the impacts of the pedagogy and how it should be implemented in other classes in the future. Again, the benefits of this methodology outweigh the costs of possible bias since without the close relationship it is unlikely that this research would be taking place.

The interview prompts were created based on the style of questions typically used in other studies that are attempting to understand student perceptions (Bradford, 2016; Diehm and Lupton, 2012). The following prompts were used in the interviews:

- Describe your experience learning science through the lens of sustainability.
- Finish this sentence for me. Sustainability is…
- Do you see a relationship between science and sustainability? Why or why not?
- How do you see your current ability to participate in science?

- How do you see your current ability to contribute to a sustainable world?

Follow up questions included (but were not limited to):

- What makes you say that?
- Can you define that term?
- What do you mean by that?
- How did you decide that?
- Did you enjoy that?
- Can you describe that to me in more detail?
- How do you know?
- Has your view on this changed over time?

The qualitative data obtained via the in-depth interviews were analyzed following the well-established method of phenomenography, combined with the theoretical basis of science identity. The sample size of 10 participants meets the requirements for qualitative phenomenology research, which suggests a sample size of 5-25 participants (Cresswell, 1998). When conducting phenomenographic educational research, the aim is to explain variation in student learning experiences (Waters, 2016). Therefore, the interviews were as non-directive as possible and the students could take the conversation in whichever way worked best for them and their communication style.

In analyzing the data, the focus was on a deep understanding of the meaning behind the descriptions given by the students. To get at the essential meaning of the experience, a common approach is to abstract out the themes and assign codes to each one. In phenomenographic research such as this, themes are essential aspects "without which the experience would not have been the same" (Waters, 2016). The themes were discovered through a thoughtful engagement with the student interviews and multiple, careful readings of the student responses.

Through this process 35 codes were created that captured the essence of the students' experiences and perceptions of learning science through the context of the sustainability curriculum. The coding process focused on understanding the student's words in the context of their life experience, classroom experience, and overarching science identity. From the original 35 codes, similar codes were grouped together. Two major grouping were formed: 1) Science Identity Traits and 2) Curricular Comments and Outcomes. There were 14 codes that fell into the Science Identity Traits group, 13 codes that fell into the Curricular Comments and Outcomes group, and 8 codes that did not fit into any predominant thematic category. After the codes were placed into the main two groups, subgroups were formed by again placing similar codes together. This process revealed 5 major Science Identity Trait group themes and 4 major Curricular Comments and Outcomes group themes (figure 1).

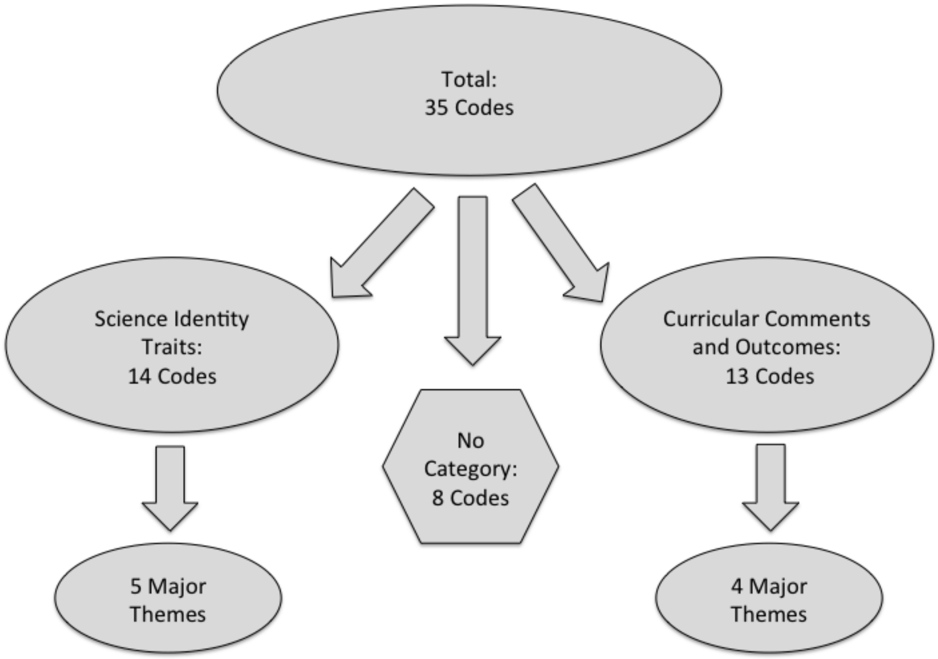

Figure 1. Breakdown of codes and theme categorization. From a total of 35 major codes two large groups were formed. Each of those large groups contains major themes that will be further discussed in results.

The overall groupings and subthemes were then analyzed in the context of previous research in the fields of science identity and sustainability pedagogy in order to reveal how student identities overlap and interact with the science and sustainability curriculum. Additionally, the codes were analyzed quantitatively. Co-occurrence tables were utilized to investigate unique and informative overlaps between codes that demonstrate students' learning experiences and highlight their science identities. Finally, a science identity "thumbprint" was developed for each student to visually and quantitatively express the differences and similarities in science identity and how that connects to STEM and sustainability learning. The results from this analysis will be described in detail in the following section.

Results

Two large motifs arose upon analyzing the interview data: 1) each student exhibited a unique combination of overlapping science identity traits and 2) students expressed shared attitudes and feelings towards the science and sustainability curriculum. Survey data supports the findings from the interviews and shows that students experienced attitudinal changes over the extent of their participation in the science and sustainability courses.

Survey Data

While there is not a large enough sample size to run statistical analysis on the survey data, it is possible to look for trends. There were 9 students surveyed immediately before and after participation in the science course. The surveys aimed to measure science and sustainability literacy by means of examining interest in science, nature relatedness, self-efficacy for the environment, and self-efficacy for science. Looking at the students as a whole, they experienced a positive shift in all 4 categories of the survey after participation in the course. Overall, the students experienced a 14% increase in science and sustainability literacy (table 2).

Survey Results					
	Interest in Science	**Nature Relatedness**	**Self-efficacy for Environment**	**Self-efficacy for Science**	**Overall**
Pre-survey score	3.18	3.80	3.54	2.86	3.30
Post-survey score	3.65	4.20	4.07	3.42	3.79
Change	**0.47**	**0.41**	**0.53**	**0.56**	**0.49**
(% Increase)	(15%)	(11%)	(15%)	(19%)	(15%)

Table 2. Students used a Likert scale from 1 to 5 to self-assess their feelings towards each category (Appendix 1). Selecting 4's and higher indicate stronger science and sustainability literacy. This summary table shows that students score higher in each category after participation in the course.

The surveys also showed that students who started with the lowest scores in each category were the students who showed the most growth by the completion of the course. For example, 4 out of 9 students scored low on "self-efficacy for science" at the beginning of the course with an average score of only 1.8 on the scale. By the end, those same students scored an average of 3.9 in that category, a 68% increase. Students who scored higher at the beginning of the class showed little to no change. This can still be considered as a positive outcome since the students began with strong science and sustainability literacy and maintained this level throughout the course. Although, it may also indicate that this curriculum is a more powerful educational tool for beginning students, early in their science and sustainability careers.

Interview Data

The interview data was analyzed under two large overarching categories, which materialized during the coding process. The first category is "science identity" or how the students integrated the class material into their personal lives and sense of self. The second category is "curricular comments and outcomes" wherein students describe their classroom experience and discuss their attitudes and skills regarding science and sustainability. The findings from this analysis illustrate how the Sustainability Education (SE) curriculum impacts individual students on a deeply personal level (science identity) as well as on a tangible level (curriculum comments and outcomes). Based on the results of this study, it seems that SE curriculum was beneficial for these Tribal College students.

Science Identity Traits:

Under the category of science identity five major themes arose, each one correlating to a style of science identity. These themes can be used to describe the type of scientist with whom each individual identifies (either fully or partially). I have called the five groups: 1) The Personal Scientist, 2) The Career Scientist, 3) The Family Scientist, 4) The Active Scientist, and 5) The Cultural Scientist. Each science identity group is described and analyzed in depth below.

Interpreting the Science Identities

Each student is unique and demonstrated an individual mix of science identity traits. To highlight these differences, the graph below shows a Science Identity "Thumbprint" for each student. To create the thumbprint the total number of identity traits demonstrated by each student was counted. Then, the number of identity traits in each category was counted so that a percentage corresponding to each identity group could be developed. Every student has a science identity totaling 100%, which is divided up among one or more of the science identity categories.

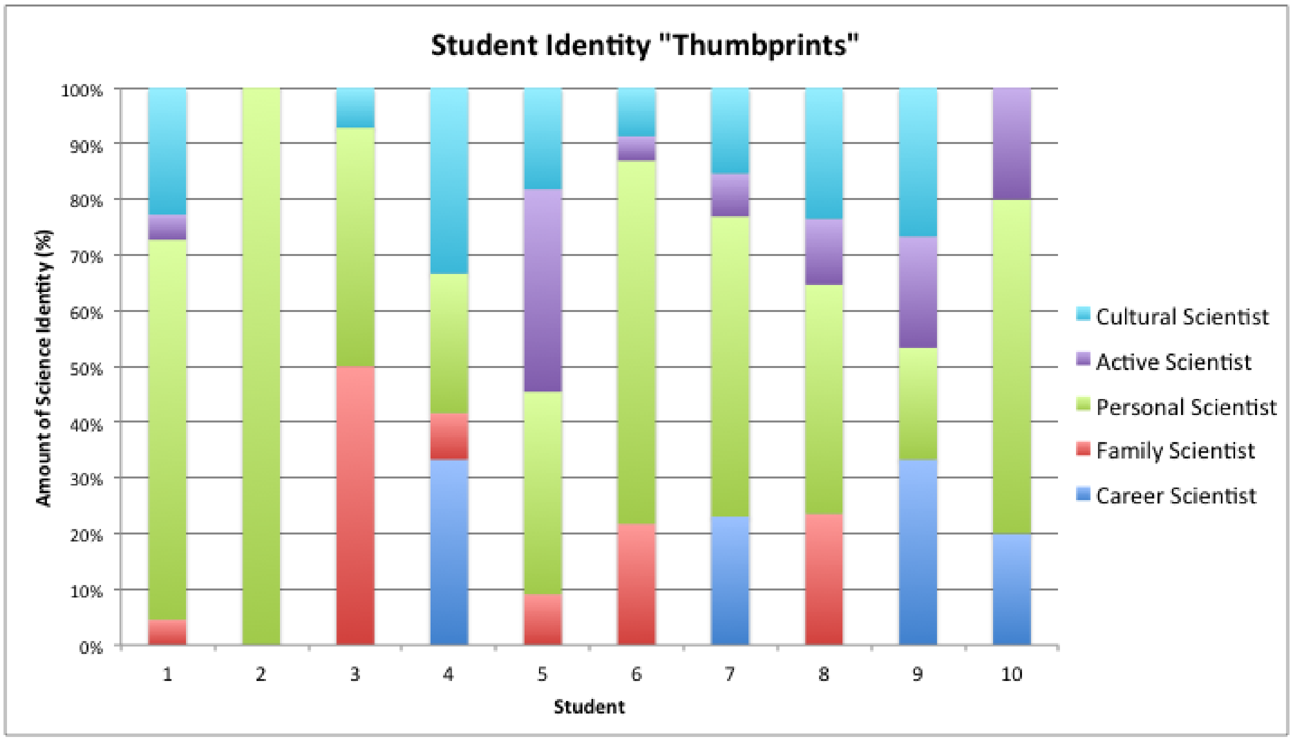

Figure 2. This graph shows the Student Identity "Thumbprints" generated from an analysis of the interview data. Each student has a science identity totaling to 100%, broken down into the percentage of traits from each science identity category they exhibited.

1) The Personal Scientist

The Personal Scientist Identity belongs to those who are interested in benefiting their own personal life through science and sustainability. Examples include gardening, making healthy choices, becoming self-sufficient, personally surviving climate change, and generally bettering themselves and their local environment.

The Personal Scientist identity was the most popular of all identities within the group of participants. Every participant demonstrated at least some Personal Scientist identity traits. Personal Scientist traits were mentioned 79 times among the 10 participants. For 7 participants this was the strongest aspect of their identity. For 2 students it was mid-range and for one it was low. One student demonstrated only Personal Scientist traits. Others showed a very high number of these traits as compared to the other areas of their science identity.

The most common sub-themes for those expressing Personal Scientist traits include growing food (mentioned 22 times), being self-sufficient (mentioned 14 times), making personal lifestyle changes (mentioned 19 times), and caring for health (mentioned 9 times).

There is a lot of overlap between the aforementioned sub-themes within each quote. For example, many people combined talking about food and health:

***"**We can do so much stuff from food. Food was one, that's a big thing, especially in native country where diabetes is a high killer, high cholesterol, high sugars, all that stuff. Like I said the one [science thing] I'd want to get into is the gardening and stuff. Would that be a science? I try to stick to everything natural, foods and all that."*

"*Yeah, and how to save the storm water, and how to plant stuff that doesn't use the fertilizer, the round up, or the chemical stuff. You just do it organically… [It's science] because you learn like, you don't need chemicals to make your food grow. And the chemicals affect you, like they affect people thinking of something with their babies or diseases and stuff."*

"And then yeah, you talk about food. We make plenty of food, we have plenty of food, but protein is expensive. It's difficult to raise, it's... you have to pen it, you have to feed it, there's a lot of negative to it. But um, if you just harvested fish, you don't have to feed them. They show up, you're good to go."

"Because I used to work on a farm and after the first year of working there when we presented the farm on the first year we went into sustainability where we were using the seeds of our own crop to spring forth the new crop for the following seasons. And our focus was to keep the cost minimal at the farm, minimum down, because everything was going out for free to the tribe, so we did what we can do to sustain the farm, at the minimum cost for the tribe."

"Science is in sustainability. I see it because you know, like I said the soil, and you showed a video about soil and farming. So the soil and the different soils around the whole world and how certain soils are good for farming. How that the food that comes from the farming areas get on to our table. You know, how they have to practice the fertilization and the different, what chemicals are bad, and what they don't want in their food or want in their plants. How that all affects us."

"People are like "I have to take omega-3 or omega 6" well you could take this [Natural and indigenous alternative], it's like 60% of your daily nutrition values and like, there's food right there. That's a big thing in America, not only just Native country. America everywhere, starvation, people can't afford even a WalMart stuff."

Many respondents also mentioned that learning about science and sustainability could help them personally survive and thrive. They stated that by understanding these topics and living by them they could become more self-reliant:

"[Science and sustainability] are important to survive. Learning to survive every situation I guess you can say."

"Because science has to do with living. I mean, what happens if we don't have the Internet or we don't have no more oil, what if everything just shuts down? You know and it's good to know about your environment and how to make things work or adapt."

"Once you start growing your own stuff it's better than going to the super market and picking up food, groceries that's been there for a couple days and once you figure out that it's actually really easy to do, to grow your own food and it tastes a lot better and you know where the actual food is coming out"

"Well, I always say if I ever got my own house I'd like to have solar panels on there. Not pay an electric bill."

Additionally, many of the students with the Personal Science Identity felt that they best way they could contribute to both science and sustainability was by changing their lifestyles:

"Oh yeah, the more I get more knowledgeable about science and our environment, the more I make different changes. Don't idle my car, you know, just little things, there's some things like I have bad habits. Like I use a lot of plastic grocery bags. I don't bring them back! And I get so mad at myself!"

"*Recycle more and compost (we learned about that). Compost and try to take care of the environment better."*

"Yeah, making people aware. Making personal strides myself, it's a little difficult to do that because you know, then you start thinking well what is the impact of one person going to do? But then of course that becomes a self-fulfilling prophecy if you can't chance yourself how can you expect to change other people. So it does start with you, ultimately."

"*Recycle or reuse, or cut down on less paper products. "Go green". Green like... we were at [a water park] and everybody had to buy their drinks and I go 'they should have those water coolers where they fill up the bottles!' "*

"Currently, what I can do to contribute to a sustainable world is to ensure that I'm not using products that are not sustainable. So if I go into a restaurant and they're using styrofoam, still, which a lot of restaurants still do. You can educate them, you can let them know, like "Hey, did you realize that styrofoam isn't biodegradable and that it's going to sit in the landfill forever? You know, there are other products that you can use and they're actually to the point now where they're not that much more expensive" Like little things like that."

"Consume less stuff. Or not consume less, buying less horrible things."

"I know, my niece, she's trying to ask me "can we do some science"? Cause I don't know, she's always trying to, and I was like "yeah, we'll do something" and then I was like, I was telling her "hey if you're going to be a scientist you can't be buying just

horrible stuff". She's like "can we buy a science kit?" I was like, "this is just a lot of plastic and not very biodegradable".

2) The Career Scientist

The career scientist identity belongs to students who are either pursuing a science degree or career, or who want to utilize science within their career. Examples include farming, working for their tribe in resource management, or starting a business that utilizes modern science and technology.

There were 4 participants who demonstrated the traits of a Career Scientist identity. The theme of careers arose 14 times among these 4 participants. For 2 participants Career Scientist was the strongest part of their identity and for the other two it represented a moderate portion of their identity. One participant is pursing a science major and plans to be the head of Fish and Wildlife at their tribe in the future. One participant is a science entrepreneur who is interested in incorporating science, sustainability, and engineering into a start-up company. One participant has worked on a farm that practices sustainable agriculture and might want to pursue this again in the future. This participant also has a strong personal interest in physical sciences and could potentially follow that to a career. The final participant is highly interested in a science career in fisheries biology connected to their tribe and has also thought about teaching science.

Two Career scientists stated that they already felt confident in their science skills before taking the course. These students felt the curriculum used was highly beneficial to their peers who might just be experiencing college level science for the first time:

"I really think this is like a recommended class for beginning students. Especially just to get them, like I said, a little wet into the science field and maybe it might plant some thoughts into people. I mean; I would probably have been in my degree a lot sooner if maybe I had taken your class. Because you don't know what's out there in the science fields, it's so open and confusing almost. And I think this kind of helped."

"The exposure to science through a sustainable lens can actually create scientists because there are a lot of people that don't really understand maybe what scientists do so they take a class that's required of them, they don't really have a major yet and they find out that they absolutely love science and they love, love the sustainability aspect of it and then three years later they're sustainable scientists!"

This sentiment seems to be validated by the aforementioned survey results in which students who scored lower on self-efficacy for science showed the most improvement by the end of the course.

One Career Scientist student gained a noticeably stronger interest in pursuing science from taking the course. The student mentioned using the class as a way to gauge if a science career really was in their future, and found that many topics in the class stimulated their interests and motivation:

"I'm kind of hoping like with these two classes, it would, I'd get more of a solid answer, a solid yes or no, like is [science] something that I could do? Is this something, I mean, I know I'd like to do it but it's like, can I really do it?"

The student went on to describe how classroom activities connected to their personal interests in rivers, flooding, dams, and fish and how this made them more interested in pursing a science career:

"I would like to help with the maintaining the fish population… I like to be outside, figuring things out. I grew up on the rivers so the river has been close to me, has always interested me because there's so much to it. Especially when you live by a river that floods... To understand how it works and to maybe prevent future home losses or property losses or cattle losses also… that would be interesting. The video we watched about the Elwha River dam, how they were studying the fish in there? That was pretty neat to me… it was pretty interesting. I was like "oh wow that looks like a lot of fun" You go out there and you shock the fish and you study them, interesting. Hopefully, if I was to work with the tribe, which is kind of where I'm going, I would like to do something to help, help preserve our reservation. Mainly our rivers. I find the river very important. Given the body is made up mostly of water as well as the earth, so I find water, the rivers, the ocean, very important."

All of the Career Scientists were fairly confident in their ability to participate in science by the end of the course.

3) The Family Scientist

The Family Scientist identity belongs to students who care about science and sustainability for their family's sake or for the sake of future generations. Examples include doing experiments at home with family or children, wanting to have scientific experiences with family members, and passing on science and sustainability interest and skills to the next generation.

There were 6 participants who showed traits of the Family Scientist identity. The theme of engaging in science with family arose 19 times among these 6 participants. For one participant the Family Scientist was their strongest identity. For two participants it was a moderate portion of their identity and for 3 it was a small part of their identity.

One spoke about gardening, fishing, and hunting with uncles and grandparents as a child. This student enjoyed learning topics that connected to their upbringing and family history:

"I think I've always been more of an outdoor person, I remember my uncle on my mom's side he had a whole garden, big outdoor garden, and a greenhouse and when we'd go visit him, you know, he'd say, you guys better go out there and get your veggies and… I was looking at my mom she was looking, it was always cool to go get your own food… out in the garden and pick it and clean it. So that's always kind of been there and plus fishing, hunting, just always learned that you take care of [the environment]."

One spoke about completing science activities with their sister and niece on a regular basis and enjoyed doing experiments in class that could also be completed at home. When discussing why they enjoyed the water filter project so much they said:

"… It's just good to know. Well, cause I'm hoping, because my sister got stuff to grow. I'm thinking we're going to do that. Try to start planting our own stuff. But the filter project it was just fun. It was just fun doing the data. I just liked that one. Just the mixing everything. It just felt like something me and my niece would do."

Two spoke about teaching their children how to live more sustainably, by means of understanding the science-based consequences.

"Yeah, I think I can learn more. I have children, you know? Because they, you know, either they're probably going to have to put me in the ground so I want them to be able to survive. I want them to be able to take care of themselves. Teach my kids how to ride horses! Keep taking them to canoe journey. Learn about, you know, how things grow, it's good to know how to put in a garden, it's good to know about climate change, and to recycle, to what else, I don't know!"

"Another, well what I was talking about was the compost. You know, learning if there was a compost site near me. Teaching my son how to recycle. We're actually going through that phase right now, where he's going through the house and if there's cardboard or papers that need to be recycled, I send him to the recycling bin almost every other day."

Two spoke about sustainability as connected to "7 generations" specifically focusing on children.

"Plus I feel like if we can remember that it all comes back to us that can provide the motivation as to why we need to support the other aspects of things. If we remember that, you know, 7 steps down the line or 7 generations down the line, that could affect something regarding us or our children, which you could say are us as well, then you're more motivated to try and keep that process of a circle going but in a positive way, not in a negative way."

Two were interested in understanding science and sustainability topics to better care for the health and well being of their children, either in general, or in the wake of environmental dangers and climate change.

"You know, for my son that has asthma. Or you know learning what fresh air is. Learning what clear water means. Learning the different things in a river. Like you know, the fungi, or what do you call those? The moss and how they develop and we know they're not bad for us, but they are contributing to our air. I guess because if you do have a kid who does have asthma, or eczema or allergies, those all tie in to one, so you know just learning what's good for him and what's not."

Two specifically spoke about children in their lives who are interested in science, and whom the participants hoped to intellectually stimulate and educate.

"[My son] loves clams. You know learning how to, the sea life, his uncles dive so he gets to hear that my brothers and them actually want to sit down and talk. They talk about that stuff and to him that's science. The whole [starfish dissection lab] was science to him. You know, he wanted to learn more, why was it, why are they like this, why are they like that? Why did your teacher say this? So it was learning about that, you know, out of our way, outside of class"

4) The Active Scientist

The Active Scientist identity belongs to students who want to use science to better understand social and environmental injustices and who care about activism and societal change. Examples include researching and being involved in the Standing Rock protests, exploring environmental injustices, and using science to find solutions and gain understanding of politics.

There were 7 participants who expressed Active Scientist traits. Among these participants Active Scientist themes were mentioned 14 times. Only one participant had the Active Scientist as (tied) for their strongest identity group. The other 6 participants experienced a low, but not negligible, level of Active Scientist traits.

Political activism including protesting and forms of direct action were mentioned 4 times by 3 participants. Of these participants 2 focused on the recent Standing Rock and No Dakota Access Pipeline (No DAPL) protests and one focused on potential future threats that they would likely fight against. The students seemed to connect these topics directly to the need for science and research:

“*Well the issue with oil, you know, people when they say, we were in Standing Rock, we were talking about, because they were trying to build a pipeline... and the reason why there's such a high demand for oil is because of our cars! We all drive cars. And there's got to be another way of doing this without having to use oil. And that's my big old, that's my thoughts "well if we don't have oil then what else?" How are we going to get places? How are we going to get places without oil? And that’s what I want to find out, I want to research. I want to learn more.”*

The students seemed to be inspired to learn more science to better understand these issues, find alternatives, and fight for their rights.

Three participants in this group lamented the “American way of life” and understood their gains in science and sustainability as acts of resistance against these norms.

“Oh yeah, with like the fish hatcheries and they got to study the rivers, study the water, the fish, the plants around it, the animals, which is, up here they're close to the army base which is a little more interesting because I don't know, I don't work with the

tribe on this but I always would wonder if the army base pollutes our river. I would like to study it. The thing though would be like if they were dumping in our river and we didn't know about it, it would be quite the fight to get them to stop because it's the government against our little tribe, so... It would be, I'd probably get pretty fired up about it."

Additionally, anti-capitalist sentiments were expressed 6 times by 4 participants; again the fight for both science and sustainability resonated with their motivation against pure profit.

"*Well I mean ultimately, cause there's other things that I want to change, but it comes into the same context, its like well you're not going to change the big people unless you can change the small people because the big people are the ones doing the most of it. But just like people say, the real way to defeat big corporations is with your dollar: don't go to them. And it's the same thing with sustainability. If you want to help the environment, well then stop doing things that hurt the environment. So it's the same thing, it all starts small."*

"Well, so I think something maybe individuals should start doing, is they should start figuring out how to be what they call off grid. But it's like, how can you survive without taking from these corporations? So something I've always wanted to do, I've always wanted to create my own [sustainable business]. So, I mean eventually, I'm going to have to, I'll have to use science if I want to create that."

"Because if there is sustainable energy then who can make money off of it? Sure you can get money off of selling the patent but then who would use it? "Oh no we have

like 500,000 people and we have this renewable energy source and energy could be free" Look at Nicola Tesla! Like his way of distributing energy though out New York was actually very safe and free, but there is no way to control who gets it and how to pay for it … But since the power company couldn't control who gets power because if someone doesn't pay the bill you can't just shut of that carrier wave, because if you shut off that one carrier wave it shuts off the entire neighborhood and city so sustainable energy won't come around until we get rid of currency."

Lastly, one student within the Active Science identity group focused on the societal nature of environmental problems and scientific progress. This student is the likely social scientist of the group, based on expressed interest.

"Well, each of those aspects are equally important if you're going to consider a giant social aspect of groups, grouping of people... but personally I think the most important would be the environmental sustainability because everything else pretty much depends on the environment working. If you don't have an environment your social structure collapse. Your social structures develop within an environment. We all come into the environment, the environment is here before us. In all honesty economics are the motivation for that sustainability, that's how I see it. So I view the environmental part being very important and the other two supplemental more or less but in the wider range of sustainability they all have an equal importance because a lot of people are motivated by the money in it, or being able, and not necessarily in a greedy sense but being able to make a living which is important in our day because that how the world works now. So it's important to sustain the economic aspect just as much as it is the environmental aspect and they're all interrelated really."

5) The Cultural Scientist

The Cultural Scientist identity belongs to those who understand the importance of science and sustainability in terms of tribal sovereignty and cultural sustainability. Examples include connecting science and environmental sustainability to cultural sustainability, finding science important for traditional reasons, wanting to conserve indigenous culture, land, and animals, and wanting to use science and sustainability to benefit tribes.

There were 8 participants who exhibited the traits of Cultural Scientists. This identity was (tied) for the strongest identity in one individual, was relatively strong for 3 individuals, and was low for 4 individuals. Among the 8 participants in this group, Cultural Scientist themes arose 25 times.

The idea of sustaining indigenous culture was mentioned 3 times by 2 participants. These students specifically noticed the connection between learning the necessary science, sustaining the environment, and keeping their culture alive.

"But they started doing the Canoe Journey in Indian Country on the side of the mountains of all these coastal tribes and it started up in Canada, people from Alaska, they were all bringing their canoes out on the ocean, in the ocean waters, paddling like the used to. And even the Indians over on the Eastern side of Washington, from Canada and all the way down the Columbia river, we used Canoes and we used horses to get where we needed to go. And we used our canoes and we would meet up and go to different certain areas like Kettle Falls and we would do our trading, and we would play our bone games, and do trading… but they brought the canoe journey back in 2005 and we're showing our people that we can still do this. ***That the ancestors are not the only***

ones that are strong, that we can do this too. *So I think that if we had to reverse [our modern lifestyles] in order to save our world then that's something we have to look into."*

All 8 of the students who showed Cultural Scientist identity traits connected their thoughts to their Indigenous heritage, tribal community, or philosophy. In fact, this was done 22 times.

"*Maybe going together with cultural ways I understand [science] more 'cause an example is food sovereignty and biodiversity I would have never thought those two were the same. I was like, well, that's pretty cool."*

"It seems like more of the non-tribal don't understand what I'm saying when I say I want to learn everything holistically, because I need to. As a tribal member I have to go back into my community and know everything."

"If we're going to talk about food diversity including plants and animals, we can no longer have that discussion without native diversity. Because they all go together. And that's true because Native way, we take care of the land a lot. And we know how to make sure it comes back, we have our feast. Say huckleberry season is right now. You go pick huckleberries, you're going to have a big feast at the longhouse and part of it is helping returning every year. And it's true, you can't just talk like, "we could just replace it, we could" – No! You got to have indigenous… we have to have indigenous minds as leadership in there because you can't talk about plant diversity, animal diversity, without having indigenous diversity because we have more connection with it here than say a scientist or someone that read about it. We know a lot more, like people from this area know more about this land than someone who went to school for it."

In general, this group tied culture to their experiences in science and sustainability and saw science and sustainability as innately connected to who they are as Native people. Major themes included thinking of sustainability in the "7 generations" context and maintaining salmon populations. However, there were a wide variety of cultural connections brought forward by the participants that are best displayed as quotes to highlight their uniqueness:

"Well in native traditions that's kind of just how it goes you look at everything and everything should or at least originally recycled into one another whether that was the food process, whether that was the social aspect weather that was looking at natural processes in the environment. The circle is considered sacred but ultimately you start to see in a practical sense how your actions affect the next thing that affect the next thing that ultimately come back to you anyways so no matter how you structure it if it comes back to you, to me that makes sense that it operates as a circle even if the circle might go in 7 different directions. That's how it makes sense to me at least."

"Yeah, to, to us [the plants are sacred]. From our family back home. So, just respecting plants and animals. You know, there's always a story and [my son] loves hearing stories. So just understanding how, how big animals play a role in our tradition, our every, almost everyday life."

"Sustainability is thinking 7 generations ahead and understanding that everything you do, everything we do as a human race is going to impact the people who come after us. So... Thinking 7 gen. I think when you can start to think 7 gen, you can really push it out. Push out that timeline and realize that people they're like "oh an oil spill it's not a

big deal, it's not going to do much" but then when you look at oh, that beach can't be used for so many years now. And you look at dams... they're like 'oh we'll dam it, what's the worst that can happen, we'll have plenty of power,' then 74 years later we're looking at a significant decline in food for the world. When you think about the Colombia River being the number one salmon producing river in the lower 48, and now there's no salmon that pass the Colombia, or pass the Coulee Dam. That was not thinking 7 gen! That was thinking immediately. It's like when you start thinking delayed gratification you're going to form a better, better community, as a world community. It's going to be better for everyone. But when you're that sort sighted you cause devastating impacts to the world!"

"The video it showed the tribe, the Elwha tribe there and how they suffered, with the loss of their fish which was their source of food and money. It kind of, it hit close to home because you know, a lot of Natives around here, a lot of tribes they do fish and bring money in from it and stuff so it was kind of like "oh wow" it kind of, tugged at you a little bit. And there's a talk about, where I live of them wanting to put a dam on the River."

Curricular Outcomes and Comments

Under the second major category "Curricular Outcomes and Comments" 4 major themes arose: 1) STEM Trauma & Recovery, 2) Science & Sustainability Connection, 3) Science Skills, and 4) Pedagogy Positives. Each of these themes emerged as students reflected on their experience in the course, and their thoughts, attitudes, and feelings towards science and sustainability, as well as the curriculum. Each of the themes is described in more details below:

1) STEM Trauma & Recovery

All ten interviewees mentioned either STEM Trauma or Recovery at least once during their interview. There were 17 incidences of past STEM trauma that were discussed. However, increased interest in science and sustainability was mentioned 18 times and a gain in confidence was noted 23 times.

Students often discussed being weak in science and mentioned feeling inadequate for a variety of topics:

“I mean like a lot of science, biology, you know, but that area is my weakest subject”

“I think there's different areas of science, isn't there? I could probably get a different area it's just the molecules and atoms and electrons and all that, that's just going over my head.”

“On the first day of this class I was like ‘I don't know anything about science, what am I taking a science class for?’ "

“Yeah, I'm not a really big science person so, when it comes to science I kind of grit my teeth because I don't like it... I can get excited about it, but then I realize what I am excited about is something I don't understand.”

Others discussed how they had previously been told they were not good enough or smart enough to participate in math and science:

“Well, it was in high school many many moons ago. We had to write about careers, pick three of them. First career was, you know, black jack dealer. The second

career was a bartender, and I, you know, I'm kind of searching... I just kind of put fish hatchery as one of my careers. And I kind of remember my teacher being like "yeah right, you're not going to go that far", that kind of attitude. And I didn't blame her because I was a high school drop out, you know I wasn't very studious at that time."

"When I was a little kid, I've told you, my teacher told us 'boys are better at math and science'. Which was cool because I got good at the reading thing and I was like "yes I don't have to do my math and that's it". Well, I kind of believed it. But as I got older, I was like 'no, you're crazy'."

Fortunately it seems that this class has a positive impact on the students and their confidence in their science abilities:

"Because for your classes, you just like you jam-packed it with knowledge. It was just crazy. No! I mean just stuff I never even thought of. It was just, it was awesome."

"It was kind of like a good beginners course for students just getting in to college. I think it kind of maybe lightens up, brightens up a light bulb in their head like 'oh wow, you know science is kind of more interesting than I thought! It's not about just rocks and this and that...' So I think this is a really good subject, especially for beginning students and that might steer future students into getting into the environmental degree. I actually do feel like this is something that would be like 'oh wow I actually like environmental science, it's not so scary.' Cause when you think of the environmental science, any kind of science, you know, it just like 'I don't think I can.' "

"I feel like I personally was a lot more involved in it wasn't just a straight lecture, do this test do this experiment then get out. I feel like everything that was presented to us

involved us in some way shape or form it regarded our opinions and validated them. So in comparison to other science classes I've taken it changed my opinion for the better regarding science and I would do it again actually."

"I feel like after this class [my ability to participate in science] increased because again like I was saying, you have to be aware of things in order to get involved in them. So I feel like now that I am aware of more things, I could get involved and I could... I know ways of finding out how to get involved in terms of scientific efforts."

2) Science & Sustainability

All students interviewed expressed that they understood there to be a connection between science and sustainability. They mentioned the interdisciplinary aspects 19 times and generally explained how they saw science and sustainability as connected 23 times.

Some noted how without scientific understand and evidence we would not be able to tackle environmental sustainability issues:

"[Science and sustainability are] almost one and the same. I mean you need your science to understand what you're doing. You know, we're a people that need numbers and substance and tangible information to understand. We can't just, you know like "oh if you cut the water off we'll go save the planet!" Where's the proof? So you need that backup, especially today, we need proof."

Some describe how working with the tribe requires their knowledge to bridge science and sustainability in order to solve problems and get work done:

"Well, I have to know from the Salmon restoration, salmon hatchery, near shore, offshore, I have to know about our climate, I have to know about our timber, our land,

our wetlands, our... I need to know how everything works. I have to build relationships with all these people. All these different entities -- state, federal, and tribal."

Others had a hard time even parsing science and sustainability apart from one another:

"I don't think there's a science that doesn't, I guess correlate, with sustainability. I think anything you, I was trying to think of the sciences but it's like, I think that anything you talk about in science can relate to sustainability. I think it would be very difficult for you to come up with one that didn't. I mean, some people, they think geologists don't deal with that, but we learned that they do."

3) Science Skills

All of the interviewees mentioned at least one topic related to understanding science and growing their science skills. There were 23 examples of explicit content knowledge being shared and 9 time that science skills were mentioned. Science was defined 10 times and sustainability was defined 28 times. There were 31 instances of how students thought they could participate in science and 26 instances of how to participate in sustainability.

Science skills that were stated included experimenting, testing, observing the natural environment, seeking science information from valid sources, identifying facts, critical thinking, and asking questions.

A large number of content knowledge facts were also recording during the interviews. Topics that were cited include correct information about: global warming, climate change, environmental sustainability, weather patterns, biological impacts, colonization, native plants and animals, fossil fuels, hydrologic fracturing, composting, soil, sustainable agriculture, photosynthesis, oxygen, biodegradability, wetlands, economic and social connections, human impact on the environment, earthquakes, drilling, glaciers, renewable energy, dams and dam removal, river geomorphology, sediments, tsunamis, genetic modification, bioremediation, ocean acidification and more.

Additionally students were asked to define both science and sustainability. The answers range greatly, but showed that students had internalized their ideas about both subjects.

One student defined science as follows:

"Science has to do with like the world, the world around us, and the climate, the education of science, or biology. Like we learned about soil and how we need it and I just learned a lot from this class and it's only been like a few weeks."

One student defined sustainability as follows:

"I think sustainability really is about living on this planet with all of, with everyone and these creatures in the best way possible and I think that's probably, I mean it's a very new thought to western culture, whereas, indigenous people, they've been doing this for, since time immemorial. They've been living sustainable."

Many saw science and sustainability as generally sharing a definition (as mentioned in the previous section):

"When it comes to science and how we look at things and how we look at things and how we observe things, whether that be in a different field of science, biology, or

geology, or whatever, it call comes back to being able to sustain it because that's how we make those observations. We observe that if we don't sustain it, animals for example go extinct. They weren't sustained and then we are able to observe the negative impacts that has on the environment. But at the same time because we've let that animal go extinct we can't observe that now, the scientific process for that has ended. So in order to not only maintain our scientific observations but increase them, that depends on sustaining what we have. And increasing what we have."

These gains in science skills, content knowledge, and the ability to broadly explain science and sustainability indicate that learning did in fact take place throughout the course.

4) Pedagogy Positives

There were 8 out of 10 students who mentioned curricular or pedagogical components of the class and why they like them. These general pedagogical positives were mentioned 18 times. In particular, "hands-on" labs and classroom activities were mentioned 16 times. Students were adamant that the amount of hands-on activities made a large impact for them and that this should be included more heavily in all science classes:

"Because it seems like you learn more. Seems like, maybe just watching the video it's telling you but then, hands-on it's like you're actually doing it."

"I mean it was simple because you know you had us do the little experiment with how much the water goes through and you know we had to figure out for ourselves how

science interacted with just simple things. I mean, simple things that people would think just plants and soil and just learning how to utilize what we have around us."

"When you do a lab and you can see all of this sediment that comes out of a free flowing water and then you see what happens to it when it's dammed, I think it definitely hits home. And then you realize "oh wow, these things are holding in a lot of sediment" and then if you've learned about what sediment does for the environment... you're kind of like 'oh shoot! That's not good!' So I think that lab definitely helps."

The other curricular components that people seemed to like the most include: interdisciplinary topics, connecting science and sustainability to their lives, practical applications, covering topics that actually interest them (i.e. sustainability of hemp production), connection to culture, dissection, experiments, activities that they could do at home with their families, material that was at a true introductory level, many different subjects covered in one class, and connecting to local environmental and social issues.

"I thought it was I thought it went over well. I enjoyed the class very much and I feel that everything that we went over is readily applicable to things that I can do in my life and things that you can make sustainable or that relate to sustainability more than I would have initially thought. So in terms of how the class was presented through that lens of sustainability I thought it was enjoyable and I thought it was very beneficial for my personal knowledge and actions that I can improve upon."

"My experience learning science through the lens of sustainability... It was a good experience. I appreciate that science is being taught through that lens because it's important that individuals who are going to be going out in the world with their degrees,

taking on the world, understand that when they get in to whatever job they may end up in, that they understand that there are a lot of different things that impact our planet negatively and they can be the change in their company or their corporation or if they're scientists themselves they, you know, get that base understanding."

Overall, all interviewed students had a positive experience in their science course and saw value in the combined science and sustainability curriculum.

Discussion

In this preliminary examination, the impact of implementing the Sustainability Education (SE) model in science courses at a Tribal College has shown to be positive. Students were very receptive to the combined science and sustainability content and interviews suggest the students see the two disciplines as one interdependent topic. The results of the surveys indicate that students obtained increases in science and sustainability literacy at the completion of the course. Interviews revealed that students' own unique science identities connected to and were supported by the SE curriculum and students saw increases in their science confidence and skills. Overall, the students generally enjoyed their experience in the course and saw a pronounced difference between the class and previous negative and traumatic STEM experiences.

During the interviews, students spoke about the connection between science and sustainability. All of the students understood the topics to be innately connected and saw value in learning about both topics simultaneously. In fact, it seems that teaching this way might actually be specifically useful for tribal work where solving interdisciplinary problems that connect science, the environment, and the local economy are especially important. This means that it is useful to implement the Sustainability Education (SE) model in science courses for practical reasons beyond learning basic science skills. Additionally, students may have been able to easily see science and sustainability as connected topics because of its similarity to Native Science, wherein science issues and "ways of knowing" are inherently interdisciplinary and multifaceted. Therefore, the integrated science and sustainability classroom may be successfully supporting traditional thought processes and cultural sovereignty.

This curriculum was successful because of its ability to connect with the unique science identity traits of each student. Additionally, now that five major science identity groups have been identified, there is a distinguishable path for growth of the SE model for Tribal College students. The identity categories of The Career Scientist, The Family Scientist, The Active Scientist, The Cultural Scientist, and The Personal Scientist each nicely connect with the prescriptions of the applied Sustainability Education (SE) pedagogy. Therefore, it seems that the SE model does have the ability to positively impact the science identity of each student, which studies show can lead to long term academic impacts (Carlone and Johnson, 2008).

In particular, Career Scientists and Personal Scientists need science course materials to be practical, readily applicable, and connected to real world problems they may face one day either at work or at home. Meanwhile, the Family Scientists, Cultural Scientists, and Active Scientists need the course materials to be relevant to lives of those they love and the needs of their communities. Since most students have a mix of science identity traits, the science classroom must have a mix of curricular methods. This can be achieved through many of the recommended pedagogical approaches of SE model including community-based research, mentoring, experiential and applied learning opportunities, and learning communities.

Beyond connecting course material to personal traits and interests, it is also vital to consider the past negative and traumatic STEM occurrences many students have experienced and how the SE model curriculum can be used for mitigation. By resonating with the students' personal science identity the SE curriculum can work to further develop and deepen their sense of science identity. This has been shown to further improve science confidence and propel students to continue in the sciences (Carlone & Johnson, 2008). The SE curriculum gives the students the ability to have positive experiences in the science classroom, which may help to overpower negative experiences they have had in the past. Due to the redefined nature of the SE curriculum, it seems that students have an opportunity for validation as budding scientists and they have the chance to overcome the trauma of not fitting into the ordinary science mold.

Finally, there were specific pieces of the SE pedagogy that stood out to the students as being particularly useful and rewarding. Students felt very strongly about the hands-on aspect of the course and echoed again and again the importance of learning through doing. They enjoyed the experiential opportunities the course provided and cited them as being the most crucial to their learning and general interest in science. In implementing this curriculum providing such experiential learning opportunities should be vital. This might be the most important aspect of the 4 core components of the curriculum, or at least it was the most tangible part that students actually recognized. Either way, it is clear from this research that students are very responsive to the experiential learning aspect of the SE curriculum.

Overall, the results of this study support previous research that shows how important science identity, personal connection, and general relevancy of material are to Native students as well as others who are typically underrepresented in the sciences. Based on this research, it seems that implementing the Sustainability Education curriculum might be one method of progressing science curriculum to better meet the needs of all students. It would be ideal if a larger scale study could be commissioned to see if these results hold true at other Tribal Colleges and Universities (TCUs) or with other groups of marginalized students. Also, it would be useful to tweak the curriculum to find out which of the core components are truly the most valuable to the students. With this additional work to corroborate the findings of this study it could be possible to confidently proclaim that this curriculum is both viable and necessary for creating a more inclusive and successful science classroom.

Conclusion

As a global community we are currently living in tumultuous times. We must deal with interdisciplinary problems of environmental, social, political, and economic unrest. One of the largest and most defining issues of this Anthropocene epoch is the ever-present and wicked problem of climate change. In order to overcome climate change, we must work together to create brilliant and resilient solutions and this cannot occur without a generation well educated problem solvers and creative thinkers. It is time for academia to recognize its importance in solving these problems and producing a diverse group people who are ready for the challenge. In particular, Science, Technology, Engineering, and Math (STEM) education needs to undergo a paradigm shift towards a more social and transdisciplinary model of sustainability education for the changing world (Gilbert, 2014). This will help to produce scientists who can not only calculate, but also can think more holistically and deeply, and apply their complex thinking skills to multifaceted global problems.

There are many changes that must occur within STEM, especially in higher education, in order to make the discipline more relevant, useful, and equitable for the current era. One way that STEM education can evolve is by implementing the Sustainability Education (SE) model. This means incorporating interdisciplinary topics into science courses by means of research-based projects, learning communities, experiential learning, and interconnected issues of local and global sustainability, with the goal of developing higher order cognitive skills. This could create students better prepared to analytically tackle modern problems. Additionally, STEM must evolve by creating a more inclusive environment for people of color, women, Native Americans, and other groups who have been traditionally excluded from science. This needs to happen not only for general social justice and educational equity, but because we need all people and all unique points of view in order to combat the combined scientific and societal challenges we are facing.

This researched aimed to discover if both goals could be met simultaneously. It looked into the relationship between implementing the SE curriculum in tribal college science classes and impacts on the students' science identity and learning outcomes. In particular, this research asked: *What are tribal college students' perspectives on learning science through topics in sustainability?*

By means of interviews and surveys, students' experiences in integrated science and sustainability courses were explored. The findings indicate that indeed science and sustainability curriculum can be successfully combined and have positive impacts on students who have been historically underrepresented in the sciences. For instance, the interdisciplinary aspect of the curriculum proved particularly useful for local tribal work and community concerns on the reservation. Additionally, the hands-on and experiential learning approach was especially engaging to the students and worked to increase their interest in science and science skills. Most importantly, the SE curriculum naturally found ways of connecting with the student's personal science identities, which has shown to be a key component in developing future scientists (Carlone and Johnson, 2008).

These results are from a small, preliminary study, but are positive and useful nonetheless. There surely need to be more work done to further understand how this type of curriculum impacts students over time, how it effects other groups of students, and which aspects of the curriculum are more vital to reaching both science and equity goals. However, these positive results can have immediate use. There was nothing in the findings of this research that indicate any negative impacts, and overall students were more thoroughly enjoying their science experience and combatting previous STEM traumas. Therefore, at minimum the institution where this study took place can continue to implement these types of STEM courses and hopefully continue to monitor their impacts on the students.

It appears that by combining science courses with the Sustainability Education (SE) curriculum an advantageous learning environment was created for the tribal college students in this study. Research shows that similar pedagogical techniques also tend to be valuable for other underrepresented groups including women, people with disabilities, Hispanic/Latino, and black students. Therefore it is possible that by implementing the Sustainability Education curriculum STEM can evolve to meet the needs of a diverse set of students while also better preparing all students to solve the complex interdisciplinary problems that are threatening our global community.

Works Cited

Adams, W. M., & Mulligan, M. (2003). Decolonizing nature: strategies for conservation in a post-colonial era. Earthscan.

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of research in science teaching*, *37*(5), 441-458.

Cajete, G. (2000). Native science: Natural laws of interdependence. Clear Light Pub.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of research in science teaching*, *44*(8), 1187-1218.

Charnley, S., Fischer, A. P., & Jones, E. T. (2007). Integrating traditional and local ecological knowledge into forest biodiversity conservation in the Pacific Northwest. Forest Ecology and Management, 246(1), 14-28.

Cole, D., & Espinoza, A. (2008). Examining the academic success of Latino students in science technology engineering and mathematics (STEM) majors. *Journal of College Student Development*, *49*(4), 285-300.

Coops, N. C., Marcus, J., Construt, I., Frank, E., Kellett, R., Mazzi, E., ... & Schultz, A. (2015). How an entry-level, interdisciplinary sustainability course revealed the benefits and challenges of a university-wide initiative for sustainability education. International Journal of Sustainability in Higher Education, 16(5), 729-747.

Corbett, C., & Hill, C. (2015). Solving the equation: the variables for women’s success in engineering and computing. *DC: AAUW*.

Dagley, M., Georgiopoulos, M., Reece, A., & Young, C. (2015). Increasing retention and graduation rates through a STEM learning community. *Journal of College Student Retention: Research, Theory & Practice*, 1521025115584746.

Dennis, J. M., Phinney, J. S., & Chuateco, L. I. (2005). The role of motivation, parental support, and peer support in the academic success of ethnic minority first-generation college students. *Journal of College Student Development*, *46*(3), 223-236.

Drolet, J., Wu, H., Taylor, M., & Dennehy, A. (2015). Social Work and Sustainable Social Development: Teaching and Learning Strategies for ‘Green Social Work’Curriculum. Social Work Education, 34(5), 528-543.

Ecklund, E. H., Lincoln, A. E., & Tansey, C. (2012). Gender segregation in elite academic science. *Gender & Society*, *26*(5), 693-717.

Environmental Protection Agency (EPA). Environmental Justice (2016, February 2). Retrieved March 06, 2016, from https://www3.epa.gov/environmentaljustice/

Estrada, M., Burnett, M., Campbell, A. G., Campbell, P. B., Denetclaw, W. F., Gutiérrez, C. G., ... & Okpodu, C. M. (2016). Improving Underrepresented Minority Student Persistence in STEM. *CBE-Life Sciences Education*, *15*(3), es5.

Ghee, M., Keels, M., Collins, D., Neal-Spence, C., & Baker, E. (2016). Fine-Tuning Summer Research Programs to Promote Underrepresented Students' Persistence in the STEM Pathway. *CBE-Life Sciences Education*, *15*(3), ar28.

Gray, D., & Colucci-Gray, L. (2014). Globalisation and the Anthropocene: The reconfiguration of science education for a sustainable future. Sisyphus Journal of Education, 2(3), 14-31.

Guerrero, M. J. (2003). "Patriarchal colonialism" and indigenism: Implications for Native Feminist spirituality and Native womanism. Hypatia, 18(2), 58-69.

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, M. C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, *47*(8), 978-1003.

Harackiewicz, J. M., Canning, E. A., Tibbetts, Y., Giffen, C. J., Blair, S. S., Rouse, D. I., & Hyde, J. S. (2014). Closing the social class achievement gap for first-generation students in undergraduate biology. *Journal of Educational Psychology*, *106*(2), 375.

Hazari, Z., Sadler, P. M., & Sonnert, G. (2013). The science identity of college students: exploring the intersection of gender, race, and ethnicity. *Journal of College Science Teaching*, *42*(5), 82-91.

Herrmann, S. D., Adelman, R. M., Bodford, J. E., Graudejus, O., Okun, M. A., & Kwan, V. S. (2016). The Effects of a Female Role Model on Academic Performance and Persistence of Women in STEM Courses. *Basic and Applied Social Psychology*, *38*(5), 258-268.

Hilden, Lee, Suzack, C., Huhndorf, S. M., Perreault, J., & Barman, J. (Eds.). (2011). Indigenous women and feminism: Politics, activism, culture. UBC Press.

Hulleman, C. S., Godes, O., Hendricks, B. L., & Harackiewicz, J. M. (2010). Enhancing interest and performance with a utility value intervention. *Journal of Educational Psychology*, *102*(4), 880.

Hobbs, F., & Stoops, N. (2002). Demographic Trends in the Twentieth Century. Census 2000 Special Reports.

Hurtado, S., Newman, C. B., Tran, M. C., & Chang, M. J. (2010). Improving the rate of success for underrepresented racial minorities in STEM fields: Insights from a national project. *New Directions for Institutional Research*, *2010*(148), 5-15.

Jostad, P. M., McAvoy, L. H., & McDonald, D. (1996). Native American land ethics: Implications for natural resource management. Society & Natural Resources, 9(6), 565-581.

Kowalczak, C. C. (2013). *Native American Students' Perceptions of the Manoomin STEM Camp* (Doctoral dissertation, University of Minnesota Duluth).

Kuenzi, J. J. (2008). Science, technology, engineering, and mathematics (STEM) education: Background, federal policy, and legislative action.

Lopatto, D. (2007). Undergraduate research experiences support science career decisions and active learning. *CBE-Life Sciences Education*, *6*(4), 297-306.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. Science Education, 95(5), 877-907.

Maughan, O. E., Bounds, D. L., Morales, S. M., & Villegas, S. V. (2001). A successful educational program for minority students in natural resources. *Wildlife Society Bulletin*, 917-928.

McCarty, T., & Lee, T. (2014). Critical culturally sustaining/revitalizing pedagogy and Indigenous education sovereignty. *Harvard Educational Review*, *84*(1), 101-124.

McPherson, S., Anid, N. M., Ashton, W. S., Hurtado-Martín, M., Khalili, N., & Panero, M. (2016). Pathways to Cleaner Production in the Americas II: Application of a competency model to experiential learning for sustainability education. Journal of Cleaner Production, 135, 907-918.

National Science Foundation, National Center for Science and Engineering Statistics. 2015. Women, Minorities, and Persons with Disabilities in Science and Engineering: 2015. Special Report NSF 15 311. Arlington, VA. Available at http://www.nsf.gov/statistics/wmpd/

Nykiel-Herbert, B. (2010). Iraqi refugee students: From a collection of aliens to a community of learners. *Multicultural Education*, *17*(3), 2.

O'Byrne, D., Dripps, W., & Nicholas, K. A. (2015). Teaching and learning sustainability: An assessment of the curriculum content and structure of sustainability degree programs in higher education. Sustainability Science, 10(1), 43-59.

Oatman, B. J. (2015). *Culturally Sustaining Pedagogy in a Science Classroom: The Phenomenology of the Pit House* (Doctoral dissertation, UNIVERSITY OF IDAHO).

Oyana, T. J., Garcia, S. J., Haegele, J. A., Hawthorne, T. L., Morgan, J., & Young, N. J. (2015). Nurturing Diversity in STEM Fields through Geography: the Past, the Present, and the Future. Journal of STEM Education: Innovations and Research, 16(2), 20.

Riggs, E. M. (2005). Field‐based education and indigenous knowledge: Essential components of geoscience education for Native American communities. *Science Education*, *89*(2), 296-313.

Roehrig, G., Campbell, K., Dalbotten, D., & Varma, K. (2012). CYCLES: A culturally-relevant approach to climate change education in native communities. *Journal of Curriculum and Instruction*, *6*(1), 73-89.

Russell, S. H., Hancock, M. P., & McCullough, J. (2007). Benefits of undergraduate research experiences. *Science(Washington)*, *316*(5824), 548-549.

Sargent Jr, J. F., & Shea, D. A. (2012). The President's Office of Science and Technology Policy (OSTP): Issues for Congress. Congressional Research Service.

Schinske, J. N., Perkins, H., Snyder, A., & Wyer, M. (2016). Scientist Spotlight Homework Assignments Shift Students' Stereotypes of Scientists and Enhance Science Identity in a Diverse Introductory Science Class. *CBE-Life Sciences Education*, *15*(3), ar47.

Semken, S. (2005). Sense of place and place-based introductory geoscience teaching for American Indian and Alaska Native undergraduates. *Journal of Geoscience Education*, *53*(2), 149-157.

Sleeter, C. E. (2012). Confronting the marginalization of culturally responsive pedagogy. *Urban Education*, *47*(3), 562-584.

Smith, L. T. (1999). Decolonizing methodologies: Research and indigenous peoples. Zed books.

Tilbury, D. (1995). Environmental education for sustainability: Defining the new focus of environmental education in the 1990s. Environmental education research, 1(2), 195-212.

Tinant, C. J., Kant, J. M., LaGarry, H. E., Sanovia, J. J., & Burckhard, S. R. (2014). Building Trust, Experiential Learning, and the Importance of Sovereignty: Capacity Building in Pre-Engineering Education-a Tribal College Perspective.

Tsosie, R. (2010). Indigenous peoples and global climate change: intercultural models of climate equity. J. Envtl. L. & Litig., 25, 7.

Ward, M., Bowen, B., Burian, S., Cachelin, A., & McCool, D. (2016). Institutionalizing interdisciplinary sustainability curriculum at a large, research-intensive university: challenges and opportunities. Journal of Environmental Studies and Sciences, 6(2), 425-431.

Wals, A. E. (2014). Sustainability in higher education in the context of the UN DESD: a review of learning and institutionalization processes. Journal of Cleaner Production, 62, 8-15.

Wiek, A., Xiong, A., Brundiers, K., & van der Leeuw, S. (2014). Integrating problem-and project-based learning into sustainability programs: A case study on the School of Sustainability at Arizona State University. International Journal of Sustainability in Higher Education, 15(4), 431-449.

Whyte, K. P. (2013). Justice forward: Tribes, climate adaptation and responsibility. Climatic Change, 120(3), 517-530.

Wilson, G., & Pretorius, R. W. (2017). Utilising Work-Integrated Learning to Enhance Student Participation and Engagement in Sustainability Issues in Open and Distance Learning. In Handbook of Theory and Practice of Sustainable Development in Higher Education (pp. 245-257). Springer International Publishing.

Wright, T., & Horst, N. (2013). Exploring the ambiguity: what faculty leaders really think of sustainability in higher education. International Journal of Sustainability in higher education, 14(2), 209-227.

Zoller, U. (2015). Research-Based Transformative Science/STEM/STES/STESEP Education for “Sustainability Thinking”: From Teaching to “Know” to Learning to “Think”. Sustainability, 7(4), 4474-4491.

Appendices

Appendix 1

INTEREST IN SCIENCE (Adult version)

The Interest in Science questionnaire on page 3 measures general interest in learning science topics and engaging in scientific activities among adults. Interest in science is considered a key driver to pursuing science careers in youth (Tai, et al. 2006, Maltese and Tai 2010) and sustained lifelong learning and engagement in adults (Dabney et al. 2011, Falk, et al. 2007). We define interest as it relates to science and the environment as "the degree to which an individual assigns personal relevance to a science topic, activity, environmental issue, or the scientific endeavor." Over time, this type of interest can lead to sustained engagement, motivation, and can support identity development as a science learner (National Research Council 2009).

About the Questionnaire

The questionnaire contains 12 items total, and can be administered either online, by telephone, or via paper. It should take about 10 minutes to administer. This version of the questionnaire can be administered as a pretest and/or posttest. Please contact us if you would like to administer a retrospective pre-post version of this scale.

This questionnaire was developed and tested in the context of a variety of informal science learning settings (primarily with participants of Citizen Science projects). Because Citizen Science participants are typically involved in learning and doing science, we recommend implementing the full questionnaire.

Cleaning your data

Some project participants will not respond as carefully as you might hope. It is important to clean your data to account for this. Once you have entered the data into a spreadsheet such as Microsoft Excel, keep the original as a master, and make a copy from which to work from. Do the following simple checks:

1.) Go down each row (i.e., individual participant) and look across the set of responses for that participant – if two or more responses are missing, exclude that row from your analysis.
2.) Once again, go down each row (participant) and look across the set of responses. Then scroll through the rows looking for sets where all of the responses are the same.
3.)

    In general, seeing the same response across all of the items is an indication that the respondent was not reading the items carefully. We recommend excluding sets where all answers are the same from your analysis *unless* the answers are all 3s, as many respondents do legitimately use midpoint responses to all questions.

Scoring instructions

These instructions pertain to the full 16-item questionnaire: Interest in Science (Adult version). Once you have implemented the questionnaire on page 3 and have your data in a spreadsheet, calculate a score for interest in science:

1.) Average together the scores for all of the items for each participant (score should be between 1-5).
2.) You can also average together the overall scores from all of your participants for an overall group score (score should be between 1-5).

Average scores below 3 indicate low levels of interest in learning or doing science activities.

Note: if you are administering the questionnaire before and after program participation and comparing the two sets of scores as part of a pre-post evaluation, you might want to consider first grouping your participants into those who started out relatively low in interest and those who started out relatively high in interest. While it is reasonable to expect an increase among participants who started out relatively low, you should not expect to see much, if any, increase in those who started out already quite high in their interest. You should consider merely maintaining that high level as a positive outcome.

INTEREST IN SCIENCE (ADULT VERSION) (remove title before administering)

Please indicate how much you DISAGREE or AGREE with each of the following statements by placing an X in the appropriate column. Please respond as you really feel, rather than how you think "most people" feel.

Choose one answer in each row.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I want to learn more about the biological sciences (e.g. ecology, zoology, evolutionary biology).	1	2	3	4	5
2. I like to engage in science-related hobbies in my free time.	1	2	3	4	5
3. I want to understand how processes in nature work (e.g. how birds migrate, why leaves change color, how bees make honey, etc.)	1	2	3	4	5
4. I often visit science-related web sites.	1	2	3	4	5
5. I enjoy learning about new scientific discoveries or inventions.	1	2	3	4	5

6. Other people would describe me as a "science person."	1	2	3	4	5
7. I am very interested in the natural sciences.	1	2	3	4	5
8. I enjoy reading about science-related topics.	1	2	3	4	5
9. I like to observe birds, butterflies, bugs, or other things in nature.	1	2	3	4	5
10. I enjoy talking about science topics with others.	1	2	3	4	5
11. I am interested in learning more about the physical sciences (chemistry, physics, astronomy, and geology).	1	2	3	4	5
12. I enjoy looking at information presented in scientific tables and graphs.	1	2	3	4	5

* This scale is still in development and subject to possible changes as testing continues

NATURE RELATEDNESS (Short Form)

The Nature Relatedness Short Form questionnaire (see page 2) is adapted from the original Nature Relatedness Scale (Nisbet et al. 2009) and the shortened version (Nisbet et al. 2013). This scale is intended to measures one's interest in the natural world. We define interest here as a tendency to direct one's attention toward, be aware of, and attribute importance to the natural world. Interest in the natural world is associated with persistence in the pursuit of positive environmental activities. This questionnaire was developed and tested in the context of informal science learning environments (primarily with participants of Citizen Science projects).

Cleaning your data

Some project participants will not respond as carefully as you might hope. It is important to clean your data to account for this. Once you have entered the data into a spreadsheet such as Microsoft Excel, keep the original as a master, and make a copy from which to work from. Do the following simple checks:

1.) Go down each row (observer) and look across the set of responses for that observer – if two or more responses are missing, exclude that row from your analysis.
2.) Once again, go down each row (observer) and look across the set of responses for that observer. Then scroll through the rows looking for sets where all of the responses are the same.

Scoring instructions

Once you have implemented the Nature Relatedness (Short Form) questionnaire and have cleaned your data, calculate the overall scores for individual participants and for the group of participants as a whole as follows:

1.) Average together the scores for all of the items for each participant.
2.) You can then average together the overall scores from all of your participants for an overall all group score.

*Note. If you are administering the questionnaire before and after program participation and comparing the two sets of scores as part of an evaluation of your program, you might want to consider first grouping your participants into those who started out relatively low in interest and those who started out relatively high in interest. While it is reasonable to expect an increase among participants who started out relatively low in interest, you should not expect to see much, if any, increase in those who started out already quite interested in the natural world. You should consider merely maintaining that high level as a positive outcome.

3.) Scores below 3 indicate low levels of interest in the natural world.

NATURE RELATEDNESS (Short Form- adapted) **(remove title before administering)**

Please indicate how much you **DISAGREE** or **AGREE** with each of the following statements by placing an **X** in the appropriate column. Please respond as you really feel, rather than how you think "most people" feel.

	Strongly Disagree	Disagree	Neutral	Agree	Agree Strongly
1. My relationship to nature is an important part of who I am.*	1	2	3	4	5
2. I feel very connected to all living things and the earth.*	1	2	3	4	5
3. I am not separate from nature, but a part of nature.	1	2	3	4	5
4. I always think about how my actions affect the environment.*	1	2	3	4	5
5. I am very aware of environmental issues.	1	2	3	4	5
6. Even in the middle of the city, I notice nature around me.	1	2	3	4	5

- This scale is still in development and subject to possible changes as testing continues
- * One of the six items included in the Short Version of the scale: Nisbet EK, Zelenski JM. 2013. The NR-6: a new brief measure of nature relatedness. Front Psychol. (4):813.
- Nisbet E. K. L., Zelenski J. M., Murphy S. A. (2009). The nature relatedness scale: linking individuals' connection with nature to environmental concern and behavior. Environ. Behav. 41, 715–740 10.1177/0013916508318748

<u>SELF-EFFICACY FOR ENVIRONMENTAL ACTION</u>

The Self-Efficacy for Environmental Action questionnaire (see page 2) measures one's confidence in their ability to effectively address environmental concerns. Self-efficacy for environmental action is associated with persistence in the pursuit of positive environmental activities. This questionnaire was developed and tested in the context of informal science learning environments (primarily with participants of Citizen Science projects).

Cleaning your data

Some project participants will not respond as carefully as you might hope. It is important to clean your data to account for this. Once you have entered the data into a spreadsheet such as Microsoft Excel, keep the original as a master, and make a copy from which to work. Do the following simple checks:

3.) Go down each row (observer) and look across the set of responses for that observer – if two or more responses are missing, exclude that row from your analysis.
4.) Once again, go down each row (observer) and look across the set of responses for that observer. Then scroll through the rows looking for sets where all of the responses are the same.

    In general, seeing the same response across all of the items is an indication that the respondent was not reading the items carefully. In particular, items 6 and 8 are "reverse coded," which means they are worded in such a way that they should receive opposite answers from other questions if respondents are answering all questions in a consistent manner. We recommend excluding sets where all answers are the same from your analysis *unless* the answers are all 3s, as many respondents do legitimately use midpoint responses to all questions.

Scoring instructions

Once you have implemented the Self-Efficacy for Environmental Action questionnaire and have cleaned your data, calculate the self-efficacy score as follows:

4.) Reverse the responses to questions 6 and 8 such that 1s become 5s, 2s become 4s, 3s stay 3s, 4s become 2s, and 5s become 1s.
5.) Average together the scores for all of the items for each participant.
6.) You can then average together the overall scores from all of your participants for an overall all group score.

*Note. If you are administering the questionnaire before and after program participation and comparing the two sets of scores as part of an evaluation of your program, you might want to consider first grouping your participants into those who started out relatively low in self-efficacy and those who started out relatively high in self-efficacy. While it is reasonable to expect an increase among participants who started out relatively low in self-efficacy, you should not expect to see much, if any, increase in those who started out already quite confident in their abilities. You should consider merely maintaining that high level as a positive outcome.

7.) Scores below 3 indicate low levels of confidence in one's ability to effectively address environmental concerns.

SELF-EFFICACY FOR ENVIRONMENTAL ACTION

Please indicate how much you **DISAGREE** or **AGREE** with each of the following statements about your influence on the environment by placing an **X** in the appropriate column. Please respond as you really feel, rather than how you think "most people" feel.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I feel confident in my ability to help protect the planet.	1	2	3	4	5
2. I am capable of making a positive impact on the environment.	1	2	3	4	5
3. I am able to help take care of nature.	1	2	3	4	5
4. I believe I can contribute to solutions to environmental problems by my actions.	1	2	3	4	5
5. Compared to other people, I think I can make a positive impact on the	1	2	3	4	5
6. I don't think I can make any difference in solving environmental problems.	1	2	3	4	5
7. I believe that I personally, working with others, can help solve environmental	1	2	3	4	5
8. It's hard for me to imagine myself helping to protect the planet.	1	2	3	4	5

* This scale is still in development and subject to possible changes as testing continues

SELF-EFFICACY FOR LEARNING AND DOING SCIENCE

The Self-Efficacy for Learning and Doing Science questionnaire (see page 2) measures one's confidence in learning science topics, engaging in scientific activities, and more generally in being a scientist. Self-efficacy for science is associated with persistence in the pursuit of science-oriented activities. This questionnaire was developed and tested in the context of informal science learning environments (primarily with participants of Citizen Science projects).

Cleaning your data

Some project participants will not respond as carefully as you might hope. It is important to clean your data to account for this. Once you have entered the data into a spreadsheet such as Microsoft Excel, keep the original as a master, and make a copy from which to work. Do the following simple checks:

5.) Go down each row (observer) and look across the set of responses for that observer – if two or more responses are missing, exclude that row from your analysis.

6.) Once again, go down each row (observer) and look across the set of responses for that observer. Then scroll through the rows looking for sets where all of the responses are the same.

    In general, seeing the same response across all of the items is an indication that the respondent was not reading the items carefully. In particular, items 3 and 7 are "reverse coded," which means they are worded in such a way that they should receive opposite answers from other questions if respondents are answering all questions in a consistent manner. We recommend excluding sets where all answers are the same from your analysis *unless* the answers are all 3s, as many respondents do legitimately use midpoint responses to all questions.

Scoring instructions

Once you have implemented the Self-Efficacy for Learning and Doing Science questionnaire and have cleaned your data, calculate the self-efficacy score as follows:

8.) Reverse the responses to questions 3 and 7 such that 1s become 5s, 2s become 4s, 3s stay 3s, 4s become 2s, and 5s become 1s.
9.) Average together the scores for all of the items for each participant.
10.) You can also average together the overall scores from all of your participants for an overall group score.

4.) Scores below 3 indicate low levels of confidence in learning project-related information and/or participating in project activities. Given that the questionnaire includes separate sets of items for learning (items 1-4) and doing (items 5-8), you might want to average those sets of responses (either for individual or group) separately to investigate whether participants are more or less confident with one or the other concept.

Note that if you are administering the questionnaire before and after program participation and comparing the two sets of scores as part of a pre-post evaluation, you might want to consider first grouping your participants into those who started out relatively low in self-efficacy and those who started out relatively high in self-efficacy. While it is reasonable to expect an increase among participants who started out relatively low in self-efficacy, you should not expect to see much, if any, increase in those who started out already quite confident in their abilities. You should consider merely maintaining that high level as a positive outcome.

SELF-EFFICACY FOR LEARNING AND DOING SCIENCE

Please indicate how much you **DISAGREE** or **AGREE** with each of the following statements about science by placing an **X** in the appropriate column. Please respond as you really feel, rather than how you think "most people" feel.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
These statements are about how you feel about learning and understanding science topics.					
1. I think I'm pretty good at understanding science topics.	1	2	3	4	5
2. Compared to other people my age, I think I can quickly understand new	1	2	3	4	5
3. It takes me a long time to understand new science topics.	1	2	3	4	5

4. I feel confident in my ability to explain science topics to others.	1	2	3	4	5
These statements are about how you feel about doing scientific activities.					
5. I think I'm pretty good at following instructions for scientific activities.	1	2	3	4	5
6. Compared to other people my age, I think I can do scientific activities	1	2	3	4	5
7. It takes me a long time to understand how to do scientific activities.	1	2	3	4	5
8. I feel confident about my ability to explain how to do scientific activities to	1	2	3	4	5