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Integrating a Sustainability Education Model into STEM Courses at a Tribal College: Building Diverse Scientists via Science Identity Development

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Indigenous scholars have been historically excluded from Science, Technology, Engineering, and Math (STEM) and are currently underrepresented in STEM degree programs and jobs. Having a population with STEM skills is crucial for rural sovereign Native American communities to manage their natural resources, infrastructures, and technologies. Thus, STEM education must be transformed to welcome and support the achievement of Indigenous scholars. This research explores the impacts of implementing a Sustainability Education (SE) pedagogy in science courses at a Tribal college that serves rural and semirural Native American students. 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 curriculum 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 and other institutions of higher learning can use this work to better understand what leads to Indigenous student success in STEM and update pedagogies accordingly.

***Keywords*: Sustainability Education, Tribal Colleges and Universities, STEM Education**

Native Americans play an enormous role in natural resource management (Jostad et al., 1996). Across the country, Tribes manage large swaths of land in rural areas and work to sustainably maintain everything from salmon populations and old growth forests to estuaries, prairies, freshwater resources, and more (Charnley et al., 2007). Additionally, sovereign nations are responsible for their own community development and infrastructure, including wastewater treatment, emergency preparedness, and electrical grids, among other things. Managing every one of these endeavors requires serious science skills and Tribes 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, typically in rural or semirural areas.

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 & 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 (SE) model that includes these topics within standard Science, Technology, Engineering, and Math (STEM) courses at the college level there is an opportunity to tap into the students' interests and allow them to better engage with science material.

To understand if integrating the SE model into STEM courses at TCUs does in fact produce these outcomes, this research investigates the following question: What are TCU 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 is 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.

The results of this study show that the TCU students are receptive to this type of hybrid science and sustainability curriculum, and therefore TCUs and other institutions of higher learning the serve Indigenous scholars can adopt this pedagogy. In doing so, there is the opportunity to propel more Indigenous learners to succeed in science and fill vital science and natural resources positions on their land and beyond.

Additionally, shifting towards a sustainability curriculum in science may not only benefits Native American students, but others who have been excluded like women, people of color, people with disabilities, and those from historically excluded backgrounds. Many of the pedagogical approaches prescribed by the SE model have been shown to create an advantageous learning environment for an extensive spectrum of students. Therefore, the SE approach should be applied and evaluated in other institutions of higher learning.

This article explores the complex nature of creating inclusive and equitable STEM education for rural and semirural TCU students, the mechanics of the SE model, and the specific needs of Indigenous learners in science. Analysis of student surveys and interviews are presented and findings on science identity traits and student opinions on the SE curriculum in STEM classes are thoroughly reported, offering insights into how results can be applied in the future.

Background

It is no accident that Native Americans, and particularly Indigenous 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). Colonial history and current manifestations 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. The US driven removal of Indian children who were sent to boarding schools caused lasting trauma and these painful scholastic experiences continue to haunt; it is no wonder that a distrust of western education has formed in indigenous communities (Smith, 2021; Tsosie, 2010). Additionally, there has been ongoing hostility towards and often an outright dismissal of Indigenous traditional knowledge in the western science classroom (Smith, 2021). When it comes to increasing participation of Native Americans in science, this is especially relevant, however, often ignored. Typically, modern problems like, rural location, small population, 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 are to the Indigenous population regarding their education, and actively work for justice and reform.

Sustainability Education (SE)

Introducing sustainability topics and classes into conventional school settings is one strategy 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 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 SE in a modern classroom. For the purposes of this research, 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 applied SE (O'Byrne et al., 2015; Wals, 2014; Wright & Horst, 2013).

The model of SE used in this study consists of: 1) development of Higher Order Cognitive Skills (HOCS) by means of problem solving and critical thinking (Zoller, 2015); 2) integrated, interdisciplinary classes combining topics of science, technology, environment, society, policy, sustainability, 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 (McPherson et al., 2016; Wilson & Pretorius, 2017); and 4) a strong interwoven focus on the environment and social justice (Drolet et al., 2015; Wiek et al., 2014).

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 (Brickhouse et al., 2000). Science identity describes how students are engaging in science and how this is related to how they seem themselves rather than simply what science facts they know. Using a science identity-based framework to understand historically excluded groups (HEG) persistence in science has proven to be a robust and trusted method (Hazari et al., 2010).

Since science identity has come to the forefront of engaging HEGs in STEM, researchers have turned to studying curriculum, pedagogies, and programs that may positively impact student's science identity. This research shows that even minor changes in curriculum (like exposing students to the academic work and personal background of diverse researchers) or creative tweaks to classroom assignments can have large and lasting positive impacts on students, their science identity, and success in STEM (Schinske et al., 2016).

Native American Teaching and Learning

While many studies focus on HEGs 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 are emphasized for a variety or HEG students are applicable for Native American students. For instance, the importance of mentors for Native American learners (Maughan et al., 2001) and the significant role of personal identity within the science classroom (Oatman, 2015). 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; McCarty 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). This pedagogical approach aligns with the importance of experiential learning opportunities, socially relevant material, and community focused practices, shown to be pertinent for the success of all HEG groups within the sciences. The biggest difference between what other HEGs 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 since time immemorial. Additionally, a place-based and culturally connected curriculum can have a positive influence on students' science identity (Kowalcak, 2013). 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.

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, and 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).

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). Trivialization 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 (NykielHerbert, 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 reality of colonialism in their courses so that their Indigenous students can triumph.

Integrating Sustainability Education and STEM for Native Scholar Success

There must be a paradigm shift within science education to better make space for HEG 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 SE it appears that there is overlap between what the SE model prescribes for science curriculum and what Indigenous and other HEG students require to succeed in STEM. In particular, implementing SE 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 combined SE 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 HEGs in STEM. It has been well documented that HEG 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 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 HEGs 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 SE pedagogy to engage HEGs 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 surveying and interviewing the student participants regarding their experience.

Methodology

The goal of this research is to understand if implementing the sustainability model within STEM classes is advantageous for rural and semirural TCU students. This study uses a purposive selection of TCU students were surveyed and interviewed regarding their experience participating in a science class that incorporated the SE 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.

Rural Reservation Study Site

This study took place at a TCU serving Indigenous students in the Pacific Northwest. The location of the research is a reservation-based branch of the larger TCU, which has a main campus and smaller site campuses distributed across rural and semirural Indian reservations. Specially, this research took place at a small site on a rural reservation with a population of approximately 600 people, and college enrollment of about 50 people. The local economy is based on natural resources (primarily fisheries and forestry) and the casino.

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 SE curriculum model. These quarter-long courses are at the freshman undergraduate level. Class sizes at this college are small, there were six students enrolled in Biology and eight enrolled in Geology.

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. This gave meaning to the material and drew students into the courses in a tangible way, while also increasing their sustainability literacy.

Student Participants

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, nine students participated in both the pre and post surveys (five from biology and four from geology) and 10 students participated in interviews (six from biology and four from geology). The following table describes the demographics of the students:

Table 1

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 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 two 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 nine 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. The survey instrument consists of 34 questions that were taken from scales developed by the Cornell Citizen Science Group.

Survey data was analyzed using a pre-post method of comparison. 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. 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 37 scoring instruction guidelines (see Appendix 1). This data is used descriptively as the sample size for this study is quite small.

Interviews

Students who were involved in the study were interviewed regarding their experience in the science course within one 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.

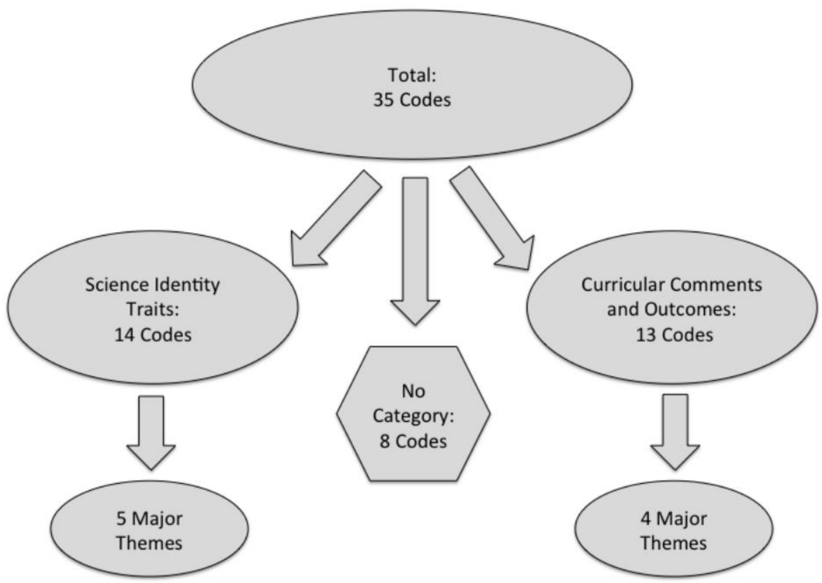
The qualitative data obtained via the in-depth interviews were analyzed following a phenomenography method, combined with the theoretical basis of science identity. The sample size of 10 participants meets the requirements for qualitative phenomenology research, which suggests a sample size of 5-25 participants (Creswell and Poth, 2016). 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. 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; eight codes emerged 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 five major Science Identity Trait group themes and four major Curricular Comments and Outcomes group themes (see 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 are further described in the 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. Code counts and 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.

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

There were nine students surveyed immediately before and after participation in the science and sustainability 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. Students exhibited a positive shift in all four categories of the survey after participation in the course, including a 14% increase in science and sustainability literacy (See Table 2).

Table 2

Survey Results

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%)

Students used a Likert scale from 1 to 5 to self-assess their feelings towards each category. Selecting 4's and higher indicate stronger science and sustainability literacy. This summary in Table 2 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, four out of nine 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 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 TCU 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). The science identity groups are called: 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, Figure 2 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 45 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

Science Identity "Thumbprints" Chart

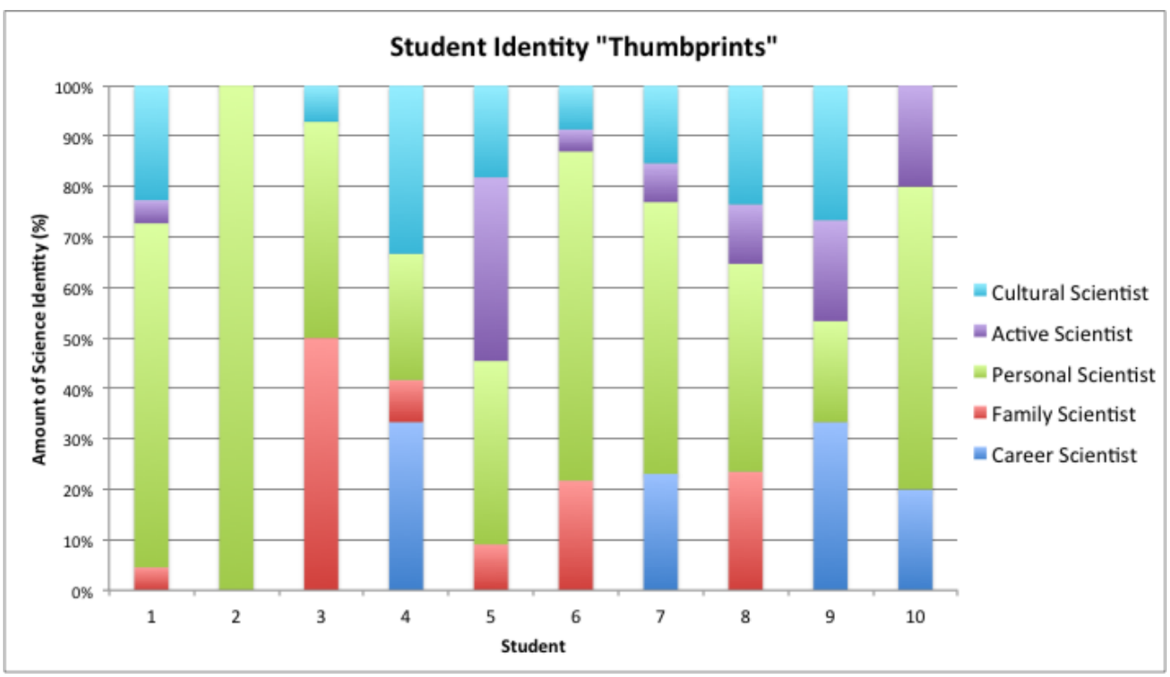


Figure 2 graph shows the student identity "Thumbprints" generated from an analysis of the interview data. Each student has a science identity totaling to 100%, broken down into the percentage of trains from each science identity category they exhibited.

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. For seven participants this was the strongest aspect of their identity. 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.

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. 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. These findings and associated quotes are shown in Table 3.

Table 3

Personal Scientist traits, interests, and supporting quotes.

Science Identity Trait & Area of Interest	Supporting Quote
Food & 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."
Self-reliance	"… 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? It's good to know about your environment and how to make things work or adapt."
Personal Choice	"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!"

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, resource management, or businesses that utilizes modern science and technology.

There were four participants who demonstrated the traits of a Career Scientist identity. One participant is pursuing 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.

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

Table 4

Career Scientist traits, interests, and supporting quotes.

Science Identity Trait & Area of Interest	Supporting Quote
Motivation	"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 this 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 [course] helped."
Interest	"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!"
Confidence	"I'm kind of hoping like with these 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? I think the answer is yes."

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 six participants who showed traits of the Family Scientist identity. Students spoke about gardening, fishing, and hunting with uncles and grandparents as children, and related this to learning topics that connected to their upbringing and family history. Some spoke about completing science activities with family members on a regular basis and enjoyed doing experiments in class that could also be completed at home. Some mentioned teaching their children how to live more sustainably, by means of understanding the science-based consequences. Several spoke about sustainability as connected to “7 generations” specifically focusing on children. Many were interested in understanding science and sustainability topics to better care for the health and wellbeing of their children, either in general, or in the wake of environmental dangers and climate change. Finally, a few specifically spoke about children in their lives who are interested in science, and whom the participants hoped to intellectually stimulate and educate. These findings and associated quotes are shown in Table 5

Table 5

Family Scientist traits, interests, and supporting quotes.

Science Identity Trait & Area of Interest	Supporting Quote
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].”
Family Activities	“… 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.”
Lifestyle	“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.”
7 Generations	“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.”
Health & Wellbeing	“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.”
Education	“[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”

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 seven participants who expressed Active Scientist traits. Only one participant had the Active Scientist as (tied) for their strongest identity group. The other six participants experienced a low, but not negligible, level of Active Scientist traits.

Table 6

Active Scientist traits, interests, and supporting quotes.

Science Identity Trait & Area of Interest	Supporting Quote
Political Activism	"We were in Standing Rock 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… 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."
Resisting Colonialism	"…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."
Anti-capitalism	"… 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."
Society & Environment	"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."

Political activism including protesting and forms of direct action were mentioned several times by participants. Participants focused on the recent Standing Rock and No Dakota Access Pipeline protests and potential future threats that they would likely fight against. The students often connected these topics directly to the need for science and research. The students seemed to be inspired to learn more science to better understand these issues, find alternatives, and fight for their rights. 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. Additionally, anti-capitalist sentiments were expressed by participants; again, the fight for both science and sustainability resonated with their motivation against pure profit. Lastly, some focused on the societal nature of environmental problems and scientific progress. These findings and associated quotes are shown in Table 6.

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 eight participants who exhibited the traits of Cultural Scientists. This identity was (tied) for the strongest identity in one individual, was relatively strong for three individuals, and was low for four individuals.

Table 7

Cultural Scientist traits, interests, and supporting quotes.

Science Identity Trait & Area of Interest	Supporting Quote
Sustaining Culture	"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 60 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."
Indigenous Heritage & Community	"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."
Cultural Connection	"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."

The idea of sustaining indigenous culture was mentioned by several participants. These students specifically noticed the connection between learning the necessary science, sustaining the environment, and keeping their culture alive. All of the students who showed Cultural Scientist identity traits connected their thoughts to their Indigenous heritage, Tribal community, or philosophy. 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. These findings and associated quotes are shown in Table 7.

Curricular Outcomes and Comments

Under the second major category "Curricular Outcomes and Comments" four 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:

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.

Table 8

STEM trauma and recovery categories and supporting quotes.

STEM Trauma	Supporting Quotations
Science Weakness & Inadequacy	"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."
STEM Trauma	"Well, it was in high school many many moons ago. We had to write about careers, pick three of them. 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."
Improved Confidence	"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."

Students often discussed being weak in science and mentioned feeling inadequate for a variety of reasons. Others discussed how they had previously been told they were not good enough or smart enough to participate in math and science. Fortunately, it seems that this class has a positive impact on the students and their confidence in their science abilities. These findings and associated quotes are shown in Table 8.

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.

Table 9

Science and sustainability categories and supporting quotes.

Category	Supporting Quotation
Science Supporting Sustainability	"[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."
Tribal Management	"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."
Science & Sustainability Interconnection	"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."

Some noted how without scientific understanding and evidence we would not be able to tackle environmental sustainability issues. Some describe how working with the Tribe requires their knowledge to bridge science and sustainability in order to solve problems and get work done. Others had a hard time even parsing science and sustainability apart from one another. These findings and associated quotes are shown in Table 9.

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 nine times 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.

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. Students provided well-conceived definitions of science and sustainability as both separate and interconnected subjects (shown in Table 10). 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.

Table 10

Defining science and sustainability.

Definition	Supporting Quotation
Science definition	"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."
Sustainability definition	"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."
Science & Sustainability shared definition	"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."

Pedagogy Positives

There were eight 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 often mentioned. 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:

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 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. Overall, all interviewed students had a positive experience in their science course and saw value in the combined science and sustainability curriculum. Examples are shown in Table 11.

Table 11

Pedagogical approaches that worked and supporting quotes.

Approach	Supporting quotations
Hands-on	"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."
Practical Application	"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."
Personal Life	"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."

Discussion

In this preliminary examination, the impact of implementing the SE model in science courses at a TCU 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 rural 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 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 TCU 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 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 & 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 western 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 four 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 SE 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 TCUs or with other groups of rural and 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 uplifting a diverse group people who are ready for the challenge. In particular STEM education needs to undergo a paradigm shift towards a more social and transdisciplinary model of SE for the changing world. This will help to educate 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, to make the discipline more relevant, useful, and equitable for the current era. One way that STEM education can evolve is by implementing the 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 is especially important in communities, like rural reservations, whose economic and cultural wellbeing is tied to the land and natural resources.

This research examined the relationship between implementing the SE curriculum in TCU science classes and impacts on the students' science identity and learning outcomes. 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 excluded 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 & Johnson, 2008).

These results are from a small, preliminary study, but are positive and useful, nonetheless. More work must be done to further understand how this type of curriculum impacts students over time, how it effects other groups of students (i.e. other HEGs and/or rural populations), 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 STEM courses with the SE curriculum an advantageous learning environment was created for the TCU students in this study. Research shows that similar pedagogical techniques also tend to be valuable for other HEGs. Therefore, it is possible that implementing the SE model can evolve STEM 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 communities on a local and global scale.

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Appendix

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

SELF-EFFICACY FOR ENVIRONMENTAL ACTION

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 <u>doing scientific activities</u>.					
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