

Review

Of Microscopes and Meeting Places: A Literature Review Examining Barriers to Indigenous Participation in STEM

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Abstract: STEM (Science, Technology, Engineering, and Mathematics) was once not seen as a place for everyone. In fact, a powerful majority of people believed that individuals had to have predetermined characteristics that made them able to bear such vast and liberating knowledge. Centuries later, concentrated efforts are still needed to reverse the damage that the prevalence of such an ideology caused. When one considers the exclusion of individuals from a particular field, they may only see one side of the story; they may think that the only factor stopping the out-group from participating is the in-group trying to keep them out. The bigger picture tells the story of the consequences of enduring exclusion of the out-group, even well after explicit exclusionary tactics cease to exist. The awareness and study of this phenomenon in regard to several groups of historically excluded people have expanded in the modern era, helping to reduce its lasting effects. Some groups continue to participate in STEM at a much lower rate than their peers. Native Americans are a particularly interesting example of this. This review will explore some of the various reasons posed for the way and rate at which Native Americans are involved in STEM education and will attempt to determine the prevalence of each explanation and their interactions with each other.



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1. Introduction

When discussing the consequences of fields within and discoveries made because of the goals and principles of STEM (Science, Technology, Engineering, and Mathematics), one is likely to cite the vast and perhaps even inspiring concept of “innovation” [1]. When pondering the environment that must be present to allow innovation to flourish and persist, one might identify the practices of challenging existing structures and beliefs, incorporating diverse perspectives and priorities, expanding knowledge, and attempting to reduce gaps in understanding while simultaneously pushing to discover new gaps as key factors [2,3]. These practices have been the direct cause of the extent to which STEM processes and values have become so ingrained in the national identities of many countries around the world and so foundational for nationwide development and economic success [4]. Both a potential cause and an effect of the growth of STEM internationally, STEM education and STEM careers are becoming more accessible to population groups that have historically been excluded from pursuing or participating in STEM [5], but one would be reasonable to argue that this change is not occurring at a fast enough pace [6].

Remnants of widespread 19th- and early 20th-century scientific racism that attempted to promote false ideas about biological, intellectual, and physiological differences between people of different racial groups persist in the modern era [6]. Perhaps one of the most apparent effects of such ideology is the extent to which STEM is considered to be a field

in which the participants are mostly White and male [7,8]. Oftentimes, the actual figures support this notion, thus perpetuating the cycle [9].

While it is true that significant effort and progress have been made regarding the expansion of STEM awareness and STEM opportunities to a wider range of the population, it is crucial that such attempts continue while bearing in mind the root reason why any type of diversity in STEM matters, whether that be diversity of race, gender, age, religion, ability, or a plethora of other factors [10]. As the barriers to the physical capabilities and the aspirations of STEM have diminished over time, the ethics of individuals within STEM fields and the ethical standards held by STEM fields as a whole have had to adjust to coexist with the growing power scientists and engineers yield in determining what is achievable. Sometimes ethical codes in STEM are seen as barriers to achievement—take the efforts to promote the gene manipulation of embryos, for example. Other times they are viewed as a guide that promotes the concentration of knowledge, development, and skill on urgent tasks, like modern efforts to slow or halt the progression of climate change and the accompanying climate disasters. Therein lies the conflict: engineering ethics are not always viewed as the thread that holds together the engineering design process, but rather as the final check before putting a design into action [11]. When considering the significant impact of engineering decisions, the need for a heightened focus on ethics within engineering becomes increasingly evident. Luckily, there is strong reason to believe that a more robust understanding of engineering ethics already exists among the current participants in STEM [11]. The remaining work exists in intentionally seeking out such knowledge, including the bearers of that knowledge, listening to what they have to say, and incorporating it into actual decisions [12].

One of the lesser-discussed case studies that can be used to better understand the discrepancy between a population's racial and ethnic makeup and the racial and ethnic composition of the population's STEM workforce lies in the experiences of Indigenous people [13–15]. This review will specifically explore the STEM experiences and perceptions of Native Americans. Just as history is written by the victors, STEM is led by the majority groups in populations [10]. This likely does not come as a shock; why would the majority group in a population not also be the majority group in STEM? At first glance, this seems like a clear line of reasoning, but upon further examination of the racial and ethnic breakdown of population data compared to the racial and ethnic breakdown of students pursuing a STEM education in college, STEM degrees earned, and workers in STEM fields, a pattern emerges. The enrollment, degrees, and careers do not match the population numbers [9,16]. In 2021, 2.6% of the population of the United States identified as at least partially Native American [17,18]. That same year, Native Americans were the recipients of just under 0.294% of the engineering bachelor's degrees awarded in the United States [9]. In 2017, Aboriginal and Torres Strait Islander people represented 2.5% of the population of Australia [19]. That same year in Australia, 0.5% of engineering students were Aboriginal or Torres Strait Islander people [19]. While some newer sources estimate the Australian population includes higher percentages of Aboriginal and Torres Strait Islander people [20], the fact remains that these ethnic groups are highly underrepresented in STEM. Some of the other racial and ethnic groups in those countries are overrepresented in terms of their share of the population compared with their participation in STEM [9,16]. This matters because diversity and inclusion in STEM contribute to a more detailed and nuanced ethical code and an environment in which people feel their identity and involvement matter [12]. Further, this is important because of the lack of conversations about this specific topic [10].

The underrepresentation of certain racial and ethnic groups in STEM education and STEM careers is a relatively well-researched, well-documented, and perhaps well-explained phenomenon regarding certain groups, like Black and Hispanic or Latino individuals in the United States, but some groups continue to be looked past in discussions about STEM participation [18]. If such research is to provide a full picture of the scope of STEM, it is crucial to not make assumptions about one group's experience based on that of another [12]. Though there has not been much research conducted into the reasons for Indigenous

peoples' relative lack of participation in STEM education compared with those of other minority racial and ethnic groups, a few potential explanations emerge based on the current literature: cost of attendance [8], general perception of scientists and engineers [9], and goal congruence [10].

This review will explore the leading explanations on this topic, determine the extent to which such differing conclusions can coexist, identify gaps in the presently available knowledge on the topic, and attempt to answer the following question: what factors have the greatest influence on the rate of Native American student participation in engineering?

2. Background

Over time, the population of the United States has slowly become more racially and ethnically diverse [21]. This is reflected, to some extent, in the decrease in the percentage of the American population that is White-alone non-Hispanic from 63.7% in 2010 to 57.8% in 2020 [21]. The population of other ethnic groups has therefore increased. Globalization and migration to, from, and within the United States have caused population groups of different ethnicities to continue mixing, which will most likely lead to an American population whose ethnic makeup is composed of a smaller percentage of White-alone individuals [21]. This fact is predicted by existing trends in American population data regarding ethnicity.

Though it may seem like a relatively straightforward process, collecting population data, let alone accurate population data, is incredibly difficult [22]. The tools the American government uses to collect data about the race and ethnicity of its citizens have a history of being flawed, including grouping people who do not belong to the major ethnic groups into the category of "Other" [23]. Further, the methods of synthesizing these collected data have frequently considered people of multi-ethnic or multi-racial makeup to be part of a separate category [22]. Admittedly, analyzing the data of hundreds of millions of people is a challenging task [24]. It is crucial to recognize, though, that the results of such studies are essentially defining the national and international visibility of entire groups of people [22].

As the United States has become more ethnically diverse, so too have universities [25]. Increased financial aid opportunities and government efforts to diversify higher education and promote inclusion in higher education settings have caused more people to be able to pursue and participate in higher education [26]. Further, such changes have caused educational disciplines at college to become composed of a more ethnically diverse student body [2]. In recent years, the percentage of STEM degrees awarded to White students was below the percentage of White people in the United States for the first time, with White alone, non-Hispanic or Latino people making up 59.3% of the population in the United States in 2021 and White alone, non-Hispanic or Latino people making up 58% of the recipients of engineering bachelor's degrees in 2021 [9,21]. Therefore, some ethnicities are represented in STEM at the university level to a higher extent than they are represented in the national population. Native Americans, however, represent 2.94% of the American population [16], yet account for only 0.294% of engineering degrees awarded in 2021 [9].

These trends have changed over time [21], but Hispanic or Latino, Black or African American, and Native American workers are still considered to be underrepresented in STEM [5]. In 2010, Black or African American alone people made up 12.6% of the population of the United States [27] and 6.0% of STEM workers with a bachelor's degree or higher in the U.S. [5]. In 2020, Black or African American alone or in combination people represented 14.2% of the total American population [27] and comprised 7.1% of STEM workers with a bachelor's degree or higher in the U.S. [5]. In 2010, Hispanic or Latino people accounted for 16.3% of the American population [27] and were 5.5% of the STEM workers with a bachelor's degree or higher in the U.S. [5]. In 2020, Hispanic or Latino people represented 18.7% of the American population [27] and comprised 7.7% of STEM workers with a bachelor's degree or higher in the U.S. [5]. In 2010, American Indian and Alaska Native alone or in combination people made up 1.7% of the population of the United States [27] and were 0.2% of STEM workers with a bachelor's degree or higher in the U.S. [5]. In

2019, American Indian and Alaska Native alone or in combination people were 2.9% of the American population [27] and still comprised 0.2% of STEM workers with a bachelor's degree or higher in the U.S. [5]. Though it is true that, in number, Native Americans make up a comparatively small portion of the American population, it is extremely discouraging to recognize that their participation in STEM careers is far from representing their presence within the American population [2,3]. Given the context of innovation and the need for a more complete view of ethics established above, one can extrapolate that this relative lack of Native American participants in STEM is hurting the extent to which these goals can be achieved [12].

3. Positionality

This study was conducted by two White researchers at a large public university in the Midwest. The researchers are American citizens and attended college in the United States. One researcher studied engineering education while in college while the other researcher is studying aerospace engineering. The researchers belong to the middle class of the socioeconomic scale. The researchers had little prior knowledge of the topic of the study aside from limited peripheral observations of racial and ethnic demographics within their particular educational spaces.

The researchers began the study with the intent to explore the process by which students form their epistemological beliefs and to use various theories to determine the capability of students to restructure their epistemological beliefs in a way that would optimize STEM knowledge growth and permanence. As the researchers conducted the initial research stage of the study, they shifted their focus to be able to more closely interact with the experiences and perspectives of a specific population group. The researchers chose to focus on Native American experiences due to the above-average presence of Native American communities in proximity to the researchers' operations.

4. Methods

This study used a non-systematic literature review methodology. This study aims to identify a gap in the currently available research regarding Native American students' perception of engineers, the causes of this characterization, and the effects of this characterization on Native American students' educational and career ambitions. To explore this focus, a search of several electronic databases was conducted.

The first search term entered into Google Scholar, Web of Science, and JSTOR was "Native American students". Google Scholar returned about 4 million results, Web of Science returned 2118 results, and JSTOR returned 364,958 results. The Boolean Operator "AND" was then added to the previous search along with the new, narrowed search term "STEM". After narrowing the search, Google Scholar returned 610,000 results, Web of Science returned 96 results, and JSTOR returned 41,576 results.

Because Web of Science only returned 96 results, it was feasible to scan through the titles and abstracts of each result that was not blatantly outside of the scope of this study. The same screening process was conducted for the first 50 or so results on each of JSTOR and Google Scholar, after which there were very few if any results applicable to the specific task. Doing so caused several categories to emerge, of which the researchers further investigated the articles specifically discussing beliefs or perceptions about STEM. All other records were excluded. Duplicates of the relevant articles between the electronic databases, of which there were several, were also removed. Similarly, if multiple of the relevant articles had overlapping subject matter, the more highly cited one was selected.

While the researchers began the research process intending to use such exclusion criteria as the age of the study participants, preferring to select studies that had focused on students in elementary and middle school, and the size of the study, preferring a larger sample size and an investigation that more clearly highlighted the differences between the experiences of people from different tribes, the available material did not lend itself well to this plan. Very few studies in which younger students were the participants were available,

and many of the resources had only studied groups from one school or institution. This development caused the researchers to expand their focus to include studies conducted among high school and college-age Native American students and studies about the general financial details of Native American individuals and their families and the costs they incur upon pursuing an education in STEM. Three studies were chosen to be included in the qualitative synthesis of this review, each with a different proposed explanation for the underrepresentation of Native Americans in STEM education.

5. Results

Over the past more than a decade, several research groups have set out to establish a better understanding of the rate of Native American participation in STEM so that institutions, both educational (e.g., primary schools, high schools, universities) and governmental, can make appropriate interventions in and contributions to the Native American experience in STEM. Three studies that each explore a different group of the Native American population and each propose distinct explanations for the extent to which Native Americans are discussed in this section. The three studies included in the results and discussion are Turner, McWhirter, Lee, Mason-Chagil, Smith, Jacobs, and Jackson's 2022 work "Barriers to STEM Efficacy and Outcome Expectations Among Native American College Students" [13]; Laubach, Crofford, and Marek's 2012 work "Exploring Native American Students' Perceptions of Scientists" [14]; and Smith, Cech, Metz, Huntoon, and Moyer's 2014 work "Giving Back or Giving Up: Native American Student Experiences in Science and Engineering" [15]. The study participants were all in pursuit of an education and had not yet started a career. While additional studies that focus on the experiences of Native Americans once they are in a STEM career exist, there is a much more direct and concise path to encouraging the uptake of a STEM education or likewise encouraging persistence in the completion of a STEM degree compared with redirecting one's path once embedded in their career.

5.1. Cost of Attendance

Turner et al. [13] and Smith et al. [15] have attempted to determine the extent to which disparities in resources at the elementary, middle, high school, and university levels affect Native American students' ability and motivation to pursue a STEM education while in college.

This proposal is not misplaced considering Native American households consistently have a much lower median household income than the median household income in the United States as a whole. In 2016, for example, the median income of single-race Native American households was USD 39,719 while the overall American median household income that same year was USD 57,616 [28]. Additionally, in 2016, 26.2% of single-race American Indian and Alaska Native people in the United States were in poverty compared to the national poverty rate of 14.0% [28]. Single-race American Indian and Alaska Native people had the highest poverty rate of any race group in the United States in 2016 [28], and figures from before and after 2016 reflect these data to a significant extent. While one might acknowledge this wealth disparity as a barrier to a Native American student being able to attend college, its impact goes much deeper than that. According to Dewees and Marks writing for the First Nations Development Institute in "Twice Invisible: Understanding Rural Native America", 54% of American Indians and Alaska Natives live in rural and small-town areas and 68% of American Indians and Alaska Natives live on or near Indian reservations or tribal land [18]. Dewees and Marks also identify that incomplete or poorly collected population data can cost Native communities important funding from federal agencies and private foundations [18]. This lost funding compounds the wealth disparity between the Native American population in the United States and the rest of the country.

The study conducted by Smith et al. [15] mainly focuses on the impact of goal incongruence on the rate of Native American participation in STEM education, but it provides background information that highlights the impact of socioeconomic status on the educational and career aspirations of Native Americans. In line with data from the United

States Census Bureau [28], Smith et al. discuss the heightened rates of poverty among Native Americans, which begs the question of access and the effect of limited resources on Native American students' perception of STEM as something they could realistically participate in. Additionally, Smith et al. allude to the impact that exploitive STEM practices and activities, especially those related to medicine and the environment, have had on Native American communities [15], which may cause many Native Americans to want to distance themselves from STEM fields. This discussion of the negative associations that Native Americans hold about STEM could have been discussed in any of the three subsections of the Results section, but one could argue that its impact is best represented as the notion of personal cost in participating in STEM, rather than belonging more to the ideas of perceptions of STEM or goal congruence. Regardless of how it is classified, personal cost is as relevant a topic as monetary cost and is particularly relevant in the exploration of this topic.

It is important to note that the discussion about the impact of the cost of attendance on Native American students' educational aspirations is not just tied to the pursuit of a STEM education. Turner et al. [13] communicate that the financial barriers present to attending college are a reason for Native American students' lower rates of attending college altogether. These in turn have rippling effects on the extent of Native American participation in STEM education at the university level [13], but they affect a wider range of fields than STEM alone.

5.2. General Perception of Scientists and Engineers

Perhaps one of the most interesting and recent theories to explain the low rate of Native American STEM degree attainment is the seemingly straightforward finding that Native American students view themselves as scientists less frequently and to a lower extent than students of other ethnicities. A study conducted by Laubach et al. [14] examines this phenomenon among Native American high school students using tests that reduce the impact of the language barrier that may exist between the students and the researchers by relying on visuals to communicate the students' perceptions of scientists. This tool, called the Draw-A-Scientist test [29], uses various criteria to analyze each student's drawing along with a brief description they write about their drawing. Based on what the scientist is wearing, their ethnicity, their gender identity, the tools and experiments in their workspace, their age, whether they are wearing glasses, and several other factors, the researchers were able to determine whether the specific perceptions of scientists held by Native American students varied by grade level, gender, and the students' level of Native American cultural tradition, defined for the study as whether a Native American language was spoken in the students' homes.

The study found that students in grade 12 had less stereotypical representations of scientists than the students in grades 9–11, as did female students [14]. The drawing portion of the study showed that the students' level of Native American cultural tradition had little effect on how stereotypical their images were, though more Native American students than non-Native American students drew scientists who were observing versus experimenting and who were interacting with plant life in outdoor settings instead of working with chemicals in traditional indoor laboratory settings. These findings along with those of Smith et al. [15] and Turner et al. [13] suggest that perceptions of scientists and oftentimes wide-reaching goals are largely shared by many members of the Native American populations that have been subjects of the studies.

5.3. Goal Congruence

Smith et al. [15] asked whether Native Americans simply have different goals than non-Native American people and whether those goals, dubbed "communal goals" in "Giving Back or Giving Up: Native American Student Experiences in Science and Engineering", just do not align with the goals favored by STEM disciplines and STEM coursework in college.

Their study [15] particularly examined “communal goal incongruence”, meaning the disconnect between the presumed communal goals of Native American students and the “noncommunal culture of STEM” as a potential explanation for the underrepresentation of Native American students in STEM at the university level. The researchers discussed and gave general background information on the strength of the Goal Congruency Theory [30], which predicts that individuals pursue and remain engaged in tasks that they believe match their personal goals and values. In the case of Native American students feeling a lack of goal alignment between them and their STEM discipline [15], this theory supports prior research that shows students, regardless of ethnicity, perceive STEM to be more centered around individualistic, rather than communal, goals [30]. The researchers acknowledged the prevalence of this goal incongruence, citing the considerable presence of Western and masculine values and practices in science and science education. The researchers suggested that the perception of STEM as primarily White and male may be linked to the prominence of individualistic career goals among the majority group that participates in STEM in the United States: White men [15]. This hypothesis finds its legitimacy in the phenomenon that the dominant understandings of success in a given field are often determined by the majority participant group. Because Native American students are an underrepresented group in STEM, their goals are not able to significantly influence those that have been established over hundreds of years. Though overcoming these barriers to goal congruence may now seem more daunting than they were initially, recognizing these challenges is the first step in reducing their impact.

The participants in the first step of the study [15] were 80 Native American STEM freshmen in their first semester. Based on the students’ input on surveys designed for the study, the researchers found that the students expressed a higher endorsement of communal work goals than individualistic work goals compared to the participants of the second step of the study. In the second step, the researchers interviewed 96 Native American students and White students in STEM and non-STEM majors. This step of the study had similar findings as the first part of the study, but it widened the findings to show that both Native American men and Native American women in STEM shared this prioritization of communal goals [15]. The researchers make a claim about the extent to which Native American students prioritize communal goals, saying that the interview data revealed that, particularly for the students who were raised within tribal communities, a communal goal orientation went much deeper than a “vague desire to help others”, and was rather a “commitment to helping their tribal communities” [15]. The third study followed up a semester later with a subsample of the Native American students and found little change in their responses.

6. Discussion

The studies conducted by Turner et al. [13], Laubach et al. [14], and Smith et al. [15] have all contributed to narrowing the research and knowledge gap surrounding the state of Native American involvement in STEM. Even though the work of these three groups took place over more than ten years, their results are still effectively the same. In fact, some of these studies discuss certain findings from other studies in the collection of three. While it is to be expected and beneficial that studies exploring the same phenomenon will have similarities, the instances of overlap that occur here are particularly helpful in facilitating the construction of a full picture of the issue and in illuminating the changes that have occurred over the ten years that the publications span.

The most impactful findings of the three studies will be briefly summarized here, in the order they were presented in the Results section. Turner et al. [13] used the method of self-reported surveys to determine the construal, salience, and relevance of barriers to STEM self-efficacy among Native American college undergraduate and graduate students, half of whom were involved in an education outside of STEM. The researchers found that financial barriers were the most powerful factor in hindering STEM career preparation, followed by lack of access, lack of preparation, lack of smarts, and lack of skill on about

the same level of construal, followed by family responsibilities, discrimination, and lack of support at decreasing levels of construal [13].

Compared to previous studies that cited discrimination as one of the main factors in determining a racial or ethnic group's participation in STEM, the work of Turner et al. [13] found that, at least among their particular group of study participants, discrimination was one of the least impactful factors in determining STEM self-efficacy. Though these findings do not discredit the work of previous researchers, it is highly encouraging that racial discrimination does not have as significant of a role in dictating the experiences of this group of Native Americans in STEM as it has at previous times or in other groups. Further, this is an important finding because it provides the foundation for interventions at the educational institutional level (e.g., outreach programs, summer bridge programs, student support groups) compared to interventions at the social level (e.g., nationwide anti-discrimination efforts), which can be much harder to come by because they have to occur on a significantly greater scale in order to be effective. This study [13] also had a large impact in that it made space for the Native American participants to report their own experiences rather than being reduced to the subjects of speculation or the recipients of assumptions. Here, they were able to communicate the extent to which specific barriers informed their educational experience on an individual, person-specific level.

In creating such an environment, the researchers were also able to avoid what they called "global barrier scores", which present data from multiple sources in a more consolidated form and are often used in studies of a similar nature [13]. Global barrier scores can sometimes make it hard to notice the nuance in various types of barriers, which makes it difficult to meaningfully address the barriers.

Laubach et al. [14] similarly used a method of self-reported data to determine the connections between age, gender, and level of cultural tradition of Native American students in grades 9–12 and their perceptions of scientists. The researchers used what many consider to be an age-appropriate tool, the Draw-A-Scientist-Test (DAST) [29], in conjunction with a writing prompt connected to the data provided in the DAST and spoken interviews with some of the study participants to clarify the data they provided via the previous two measures.

Laubach et al. [14] took the exploration of Native American involvement in STEM education a step further, and one may argue a step deeper, than either of the two other studies discussed here and most of the studies that exist within this topic. They did this by conducting their research in a pre-college educational context in which some of the participants were as many as four years away from being what is traditionally college age [14]. The main reason for these choices of setting and participants was the fact that, as identified by the U.S. Department of Labor [31], students belonging to racial or ethnic minority groups, among a few other underrepresented social groups, do not pursue a STEM education in college or STEM learning in general at rates anywhere close to those of ethnic majority groups.

Though not explicitly stated, perhaps one of the goals of Laubach et al. was to identify the point at which students belonging to ethnic minority groups decide whether to pursue STEM education. If this is the case, it could be argued that solutions developed because of such findings would reduce the need for an overhaul of solutions later to attempt to attract and maintain Native American students in their STEM degree path in college. The explicitly stated purpose is to explore underrepresented students' perceptions of scientists to be able to identify the stereotypical views these students hold, and further, to use these findings to develop solutions that work towards dismantling those specific stereotypical views to make students view STEM education as attainable for them [14].

The researchers justified using the DAST to attempt to explain the rate of Native American participation in STEM by working under the assumption that students' drawings of scientists reflect their career goals and aspirations [14]. At the time of publishing, previous research providing direct evidence to support this assumption did not exist. This does not discredit the study's findings, though it does encourage the reader to analyze the

findings presented in studies that used different methods and make decisions based on the wider foundation of knowledge.

Laubach et al. [14] established the setting of their study in detail, which serves many purposes, among which is that it made clear that the school in the study has significant differences compared to other schools whose student body is primarily Native American. The school requires a minimum GPA of 2.25, three letters of recommendation from previous schools, good past attendance, “proficient” state test results, and membership in a federally recognized Native American tribe. Additionally, the school is regionally and state-accredited with stricter graduation requirements than those of the state. In the context of the lack of access to education and the lack of school resources and college preparation that many Native American students face, this school seems to be in stark contrast.

Though the results of this study may not reflect the academic environment and experiences of all Native American students, it does not pretend to do so. The gaps left by this study only serve to encourage other researchers to continue the work started here.

The participants in Laubach’s study [14] included 133 Native American students in grades 9–12 who were enrolled in science courses at the school. Their ages ranged from 14–19 years old, with most of the students being concentrated in grade levels 9–10. A total of 81 of the students were female, and 52 were male. The DAST was administered by the lead researcher during the students’ science classes during a period of three weeks within one month. The students were each identified by a number, rather than a name, to maintain participant confidentiality. The students self-reported their age, grade level, gender, and the languages they spoke at home from most to least used. The researchers used that final detail to establish what they called each student’s “level of Native American tradition”, as they were operating under the findings of previous studies that concluded that the preservation of traditional Native American language and culture at home is correlated with practicing Indigenous science at home. The students were then signaled to complete the DAST with the prompt “Draw a scientist at work in the space below”.

Though this prompt has been used with the DAST since its creation, it may be worthwhile to think about whether it belongs in the process of administering the DAST to students in this age group and at this experience level [14]. Perhaps this prompt could be undermining the knowledge of STEM and STEM workers held by the participants. Maybe more specific questions could have been appropriate, though ones that still get to the heart of what the DAST is trying to determine the following: how do Native American students perceive scientists? If a more direct question like this had been asked, meaning asking the students “how do *you* perceive scientists?”, less extrapolation likely would have had to be performed, and such a question could have perhaps had a larger impact on the participants themselves and would have pushed them to answer that question for themselves: “what do scientists *do*? What do they *look like*?” And upon their own processes of further reflection, perhaps the students would ask themselves: “does it always have to be this way?”

As mentioned before, the researchers who conducted this study knew that they did not answer every question surrounding this topic, but this is a good thing. It opens the door for new studies conducted among different Native American groups to take place. The two alternate questions proposed above could perhaps be implemented in a future study.

The drawing materials provided to each of the students in Laubach’s study [14] included a piece of white paper and either a pencil or a pen. On the next page, the students were prompted to “Explain what the scientist is doing”, the responses to which were analyzed alongside the students’ drawings as they were used to clarify or expand upon the visuals. After the students completed the DAST, about 10% of them were interviewed by the researchers to confirm the details in their drawings and written responses.

Following the data collection process, the researchers gave each drawing a score based on the presence of certain details, dubbed “upper subscale items” and “lower subscale items”, which refer to “traditional stereotypical images” and “alternative stereotypical images”, respectively, as identified in Chambers’ 1983 study [29]. Upper subscale items include a lab coat; glasses; facial hair; research symbols like scientific instruments and

lab equipment; knowledge symbols like books, filing cabinets, clipboards, and pens in pockets; technology; and relevant captions like scientific formulas. Lower subscale items include male gender; Caucasian; indications of danger like fire, explosions, and hazardous materials; lightbulbs; mythic stereotypes; indications of secrecy; working indoors; and middle-aged or elderly scientists.

Each of the students' drawings was scored on a scale of 1–15 based on the presence of each indicator, where higher scores indicated more stereotypical details in the drawing. The researchers include a valuable statement regarding misplaced interpretations of the students whose drawings had fewer stereotypical details, noting that other researchers [32] had previously found that low DAST scores were linked to an underdeveloped perception of scientists rather than a non-stereotypical perception of scientists, due simply to the lack of indicators present in the drawings.

The researchers then begin discussing the results they found, presenting the quantitative data in charts along with copies of the drawings the students provided to give additional context and insight into the study [14]. Of the scientists in the drawings, 95% were White, 86% were male, 50% were wearing glasses, 48% were wearing a lab coat, 91% were working indoors, and 89% were conducting research. These overall trends were then broken down by grade level, gender, and level of Native American tradition to better analyze the patterns within the larger group.

Most students in each of grades 9–11 wrote that their scientist was performing some sort of experiment (76%, 60%, and 63%, respectively), while 47% of grade 12 students did. A total of 32% of grade 12 students wrote that their scientist was observing, compared to 7%, 19%, and 17% for students in grades 9–11, respectively. Very few students wrote that their scientist was communicating (7%, 7%, 17%, and 5% of students from grades 9–12, respectively) [14]. Of these few cases, most described a teacher conveying information in a science class context. This detail perhaps suggests that the students' science teachers are the main or at least the most influential figures in the students' lives who practice STEM.

Grade 12 students showed scientists using scientific tools, such as magnifying glasses or microscopes, at a higher rate than the other grade levels, with more than half of their drawings and/or written responses including this detail. Of the male students, 21% drew a scientist with facial hair, 100% drew a Caucasian scientist, and 92% drew a scientist working indoors. Of the female students, 9% drew a scientist with facial hair, 78% drew a Caucasian scientist, 93% drew a male scientist, and 90% drew a scientist working indoors [14]. The presence of other indicators was shared evenly between the male and female students.

The main significant difference between the drawings produced by the Native American and non-Native American students was the type of work that they drew their scientists performing. A higher percentage of Native American students showed their scientists observing plant life outdoors than their non-Native American classmates did, which shows differences in the type of science being performed and the level of formality in the setting [14].

The researchers recognize that they are extrapolating to a significant extent to better connect their results to the social phenomenon of Native American participation in STEM using the findings of previous studies that discuss how learning in traditional Native American cultures relies heavily on observation [14]. These details, though they are less obvious than other results of the study, are crucial in beginning to understand why so few students with strong connections to their Native American identity and culture participate in STEM, especially in the context of none of the study participants drawing an aspect of Indigenous Science practices.

Perhaps a future study could employ tools to gain a clearer understanding of the students' understandings of Indigenous Science and their ideas about where Indigenous Science fits into STEM fields as they currently exist on a global scale. One method of achieving this could be to prompt the students to draw someone practicing Indigenous Science in addition to the earlier prompt to draw a scientist at work. Similar interview questions as the ones used in the study could also be used in a redesigned study to

explore any details that may have been missed in the students' drawn expressions of their perceptions of scientists.

Smith et al. [15] look to the Goal Congruence Theory, which was devised and popularized by Diekmann [30] in 2010, to attempt to explain the lack of Native American participation in STEM. Like Turner et al. [13], Smith et al. focused their investigation of the topic at the college level [15]. The study participants were composed of students from two universities with above-average Native American population numbers, Northern Arizona University (NAU) and Montana State University (MSU). In addition to having large numbers of Native American students, the Native American student population at the two schools has a mix of Native American students who grew up within traditional tribal communities in urban or nontribal areas and within traditional tribal communities in rural or tribal areas [15].

Both universities have communicated their dedication to serving the Native American portion of their student bodies, which means that this study may find lower rates of communal goal incongruence among Native American students than those of students at schools with smaller Native American populations or at schools that are less dedicated to supporting the success of their Native American students. This is not a weakness of the study, however. In fact, this study examines and communicates some of the ways that interventions at the institutional level can impact the STEM experiences and persistence intentions of Native American university students. The study setting essentially highlights the reason why this study and studies like it are crucial to bringing visibility to such issues.

The researchers then define the two main types of goal alignment: communal goals and individualistic goals [15]. The researchers briefly discuss what both goal types mean, saying that individualistic goals prioritize the success of the individual while communal goals prioritize the success of the larger group and function on connecting with others. The researchers establish the relevance of their study and its specific methods that facilitate learning more about the rate of Native American participation in STEM by talking about previous research that connects individuals' goal congruence with the tasks they are involved in and their pursuit and persistence [15]. The researchers hypothesize that the Native American STEM students will have greater communal goal incongruency than the Native American students pursuing a non-STEM education. Additionally, they anticipate that the students' belonging uncertainty will be correlated with lower motivation for STEM [15].

The researchers [15] conducted three studies to test their hypothesis. The first study included 80 Native American freshman STEM majors, of which 24 different tribal nations were represented, 56.3% were female, the median age was 21.8 years, and 70% were from MSU. The students participated in a self-reported survey during an on-campus Freshman Native American orientation event about one week before classes started [15]. The participants responded to a survey asking them multiple-choice questions about their personal interests to be able to gauge their endorsement of work-related values. The survey questions were presented on a rated scale, and participants were prompted to rank each goal as not important, somewhat unimportant, somewhat important, or very important [15]. The survey results for each question were then given a number on a scale of 1–4, with 1 indicating that the survey respondent indicated that the scenario provided in the prompt was not important to them and 4 indicating that the scenario in the prompt was very important to them.

Four of the survey prompts asked about a communal goal-related scenario and nine asked about an individualistic goal-related scenario, and the other survey items were filler and had no connection to either communal or individualistic goals [15]. The researchers performed a one-sample *t*-test, which showed that the group highly endorsed both communal work goals and individualistic work goals. The researchers also performed a paired-sample *t*-test, which indicated that the participants endorsed communal work goals significantly more than individualistic work goals. The results of Study 1 did not

differ by participant gender or school affiliation [15]. The first study was important because its findings provided a basis for the following two.

The second study consisted of 96 White and Native American students from both schools. Of the 47 White participants, 51.1% were female, 51.1% were STEM majors, and 63.8% were from NAU. Of the 49 Native American participants, 51% were female, 49% were STEM majors, and 22.4% were from NAU [15]. All of the participants in the second study were enrolled in their first semester at college. The Native American students were recruited via emails, phone calls, outreach events, and fliers. The non-Native American students were primarily recruited from introductory psychology courses at both universities during the first three weeks of the first semester [15]. In short, the students' participation was voluntary, which perhaps implies another defining characteristic of the participant groups: they found the study to have enough value and relevance to motivate them to participate.

The participants met with a research assistant and completed the same survey on paper that was used in Study 1. There were additional items in the Study 2 survey that assessed the students' familiarity with STEM and their feelings of preparedness for STEM courses. The participants rated their agreement with statements about their confidence in certain STEM subjects on a 1–5 scale, and they rated their familiarity with eight STEM fields on a 1–4 scale [15].

Analyses of variance were performed on the results, which found no significant differences between men and women, or between White and Native American students in terms of familiarity with STEM fields and confidence in STEM. As expected, students in STEM were more familiar with STEM domains than non-STEM students. The ANOVA revealed no difference in STEM confidence between men and women, between White and Native American students, or between STEM and non-STEM majors [15]. This suggests that, at the beginning of the school year, Native American and White students in STEM felt similar levels of confidence in and familiarity with STEM. Another ANOVA was performed on the standardized individualistic work goals results and showed that, overall, Native American students endorsed individualistic goals more than White students.

Another ANOVA was performed on the standardized communal work goals results and found that White men in STEM reported the lowest levels of communal work goals, and Native American men and women in STEM majors and White women in STEM majors endorsed significantly higher levels of communal work goals than the other groups of students [15]. The ANOVA also showed that Native American men and women generally identified with communal work goals at the same rate regardless of their major, with one exception: Native American women in STEM majors endorsed communal work goals to a significantly greater extent than all non-STEM majors [15].

Study 2 found that individualistic goal endorsement did not vary with gender, major, or ethnicity. Communal goal endorsement, on the other hand, was much more dependent on student gender, ethnicity, and major. Study 2 also revealed that Native American students in STEM endorsed communal work goals more than White men in any major and that White men in STEM endorsed communal work goals the least compared to all other groups [15]. This finding gives significant support to the claim that people with high levels of communal goal endorsement, like the Native American students in this study, tend to participate less frequently in STEM than people with lower levels of communal goal endorsement, like the White men in this study. This detail brings much-needed visibility to a national and international phenomenon that was previously primarily the subject of speculation.

The researchers developed a final question to guide the third step of their study [15]: to what extent are Native American students' lived experiences in STEM and their intentions to persist in their STEM education predicted by their work goals? The researchers hypothesized that the more someone values communal work goals, the more that person may experience goal incongruence while participating in a STEM education and that such goal incongruence is expected to emerge as belonging uncertainty [15].

The third step of the study was split into a survey section and an interview section. The participants in the survey section of the third part of the study included 32 Native American STEM majors who had participated in Study 2 and who had, by the time of Study 3, completed their first semester. This group was intentionally chosen so that the diversity in tribal affiliation and major of the Study 1 and Study 2 participants was represented [15]. The survey packet included an academic belonging survey, an intrinsic motivation survey, perceived performance questions, and questions about persistence intentions.

An ANOVA was performed with the survey results, and it determined that there were no meaningful differences based on gender or school [15]. The surveys did reveal, however, that the Native American STEM students with strong communal work goal endorsement at the start of college had lower self-reported motivation, weaker persistence intentions, and reported poorer performance in their courses. Additionally, the more participants valued communal work goals at the start of college, the lower their sense of academic belonging was one semester later [15].

In the second part of Study 3, 33 Native American students, including all 32 of the students from the first part of Study 3, along with 1 student from Study 1, were interviewed. The interviews ranged from 30 to 90 min. Following the interviews, the data were input into qualitative data software to analyze it. In addition to presenting the overall trends found between the students' responses, the researchers also include several excerpts from the interviews, which supports the researchers' intentions in showing that qualitative data and specificity matter [15].

The entire study serves to determine the reasons for which Native American participation in STEM at the university level is proportionally so much lower than that of other ethnic groups. In conducting their study, the researchers conclude that the individualistic nature of STEM and STEM education itself is a deterrent to participation for people who value and identify with high levels of communal work goals. The perception of STEM as individualistic connects with its strong roots in Western culture and ideology, which highly values individual achievement and goal orientation. In presenting the study participants as people rather than data points, the study goes against the traditional STEM grain, which shows that including people with goal alignments that differ from those held by the majority group in STEM means expanding the goal alignment of STEM, not restricting the allowed goal alignments of *those who participate in STEM*.

Many of the students who were interviewed expressed their desire to give back to their Native American communities using their college education in their particular STEM field. Many of the students interviewed grew up in or near tribal reservation communities, and of these students, most communicated wanting a career that allows them to contribute in some way to their Native American communities. Even students with more individualistic work goals discussed the strong expectations for those in their community to pursue a communal goal-oriented career. Nine of the eleven students who did not grow up in or near tribal reservation communities communicated having individualistic career orientations with little mention of community contributions [15]. A total of 68% of the students interviewed from tribal communities and 18% from nontribal communities expressed having communal goals [15]. This detail encourages future researchers to understand and include the nuances of Native American experiences and identities and to avoid presenting data gathered in studies of Native American students as monolithic.

Each of the three studies discussed here proposed and tested a different hypothesis for the lower rate of Native American participation in STEM compared to that of other ethnic groups. Despite them all having different settings and methods, their results were effectively the same. The study conducted by Turner, McWhirter, Lee, Mason-Chagil, Smith, Jacobs, and Jackson [13] concluded that of the many barriers Native American students face in pursuing a STEM education while in college, Native American students perceived financial barriers as the most noticeable and relevant. The study conducted by Laubach, Crofford, and Marek [14] found that Native American students do not perceive scientists as representative of their ethnic or cultural identities. Smith, Cech, Metz, Huntoon, and

Moyer [15] concluded that Native American students' heightened levels of communal goal endorsement compared to people of other ethnicities, primarily White people, causes them to feel like they do not belong in STEM due to its individualistic nature as informed by Western ideals and practices. All three studies essentially found that many Native American students face unique and personal barriers to participating in STEM that cannot be easily resolved due to their systemic causes.

7. Study Limitations and Ethical Considerations

Many problems exist with these methods of conducting studies and analyzing the data collected that could potentially cause the lack of understanding and awareness of Native American issues to persist. With 574 federally recognized Native American tribes in the United States [33], it would be incredibly difficult to gather accurate, full-picture data about each tribe's overall perception of scientists. Further, it would be nearly impossible to meaningfully analyze and share these data while maintaining the nuance of each tribe's and each tribe member's perspective. Ethical dilemmas also exist in conducting this research.

If the goal of such studies is to examine Native American perceptions of STEM so that increased Native American participation in STEM can be encouraged and facilitated, visiting Native American students in their middle or high school classrooms while not speaking their language could further the students' perception that they are more likely to be the subjects of studies than the researchers conducting studies. Studying Native American populations could perhaps compound the barriers Native American students face in pursuing STEM.

Despite the potential for individual or community harm, the presence of these ethical considerations should not serve to discourage further explorations of this topic. Rather, these ethical considerations should inform the methods, setting, and proposed interventions of future studies so that institutions and individuals involved in the issue feel empowered to contribute to improving inequitable conditions and reducing isolating practices in STEM education.

8. Future Work

To further the search for the answer to the question "what factors have the greatest influence on the rate of Native American student participation in engineering?", the researchers will develop a study and carry out research in the field. Based on the findings presented in this article, the researchers will focus their investigation on the connection between the personal costs a sample of Native American students' experiences and their perception of engineering and engineers. The researchers will consider the impact of student age on their perception of engineers, preferring to conduct the study at the elementary or middle school level. Doing so would provide more time for interventions on the institutional level based on the study findings. Additionally, the researchers will consider the impact of the tools presented in the study for the study participants to use, preferring to provide drawing materials, writing prompts, and interview questions that best allow the students to express their full span of knowledge and the most details about their individual perceptions of STEM and how it relates to their various intersecting identities.

9. Conclusions

The results and conclusions discussed in each of the three studies included in this article [13–15] attempted to narrow the knowledge gap surrounding the reasons for the comparatively low rate of Native American participation in STEM by focusing their investigations on Native Americans in academic settings. They all propose different explanations for the phenomenon's occurrence, but it could be argued that making such clear distinctions is restricting the extent of progress that can be made regarding this issue. All three studies essentially conclude that the lack of Native American involvement in STEM is an issue of perceived personal cost. This idea of personal cost includes financial barriers and identity-related concerns. As seen in the results of the studies [13–15], students may

feel confident in their STEM abilities, but they do not feel that their identities or goals are represented to the extent that would make them feel welcome or capable of contributing in the way that contribution and success is traditionally defined in STEM.

These barriers continue to exist due to the intentional restriction of STEM to specific population groups that occurred in the past, and though progress has been made toward promoting and seeking out diversity, equity, and inclusion in STEM, the way we present and perceive STEM itself often deters many. The personal cost concerns felt by Native Americans are not being reduced sufficiently to attract this population group. Perhaps this is why progress has remained stagnant for many years.

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