RESEARCH REPORT

Integrating Indigenous Science, Culture, and Social Justice Concerns into First-Year STEM Curriculum:

Improving Intellectual Growth, Psychosocial Factors Associated with Retention, and Academic Achievement of Students from Racially Minoritized Groups Historically Underrepresented in STEM

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Abstract

Deficits in college degree attainment limit important perspectives and ways of knowing that inspire creativity and innovation. Disproportional outcomes for racially minoritized groups that are historically underrepresented in science, technology, engineering, and mathematics exacerbate this problem and promote societal inequities, structural racism, professional segregation, and racial wealth gaps. Culturally responsive programming that incorporates empathy and equity for non-majority populations can empower students from diverse backgrounds to achieve their educational goals. This paper describes the outcomes of a first-year place-based learning community in which students studied the science, culture, values, and social justice concerns of the Indigenous people of the Klamath River Basin by completing a water quality experiment alongside faculty, Indigenous scientists, and cultural experts. A combination of survey data and thematic analysis was used to evaluate the impact of the program on intellectual growth, gains in psychosocial factors associated with first-year student success, and academic achievement. All student participants demonstrated intellectual growth and gains in psychosocial factors associated with STEM retention, but the effects were most pronounced for students who identified parallels between issues faced by Native American communities and their home communities. The most significant gains in STEM retention and academic achievement occurred for URG students (students from underrepresented groups) who learned about Native American culture through the water quality laboratory. The majority of students expressed the importance of understanding the cultural, environmental, and/or social justice issues of Native American people to their future careers. We believe ours is one of the first studies that specifically examines the improved outcomes for first-year URG college STEM students that can result from curriculum that highlights scientific, cultural, and social justice concerns of Indigenous communities.

Introduction

Deficits in college degree attainment limit important perspectives and ways of knowing that inspire creativity and innovation (Hong and Page, 2004; Kozlowski et al., 2022). Disproportional outcomes for racially minoritized groups that are historically underrepresented (hereafter referred to as URG) in science, technology, engineering, and mathematics (STEM) (NCSES, 2021) exacerbate this problem and promote societal inequities, structural racism, professional segregation, and racial wealth gaps (Chesky and Wolfmeyer, 2015). Student motivation to overcome barriers to persistence, retention, and graduation is increased when they see connections between their educational experience, community values, and career goals (Mishra, 2020). Linking STEM content to equity and empathy concerns is particularly impactful on URG student motivation and STEM retention, especially when students are presented with STEM career possibilities that integrate opportunities to address social and civic issues (McGee & Bentley, 2017; Gray et al., 2022). First-year STEM learning communities that include educationally purposeful activities within and outside the classroom can also create a sense of belonging, enhance student engagement, and promote personal development to result in improved graduation rates (Otto et al., 2015).

To improve STEM success at our university, we created a first-year place-based learning community called Klamath Connection (Johnson et al., 2017; Sprowles et al. 2019), which explores the science, culture, civic, and social justice issues of the Native American people of the Klamath River Basin. In August 2007, water quality scientists from the Karuk Tribe of California discovered *Microcystis aeruginosa (M. aeruginosa)* behind the Klamath River dams[1] (Kann & Corum, 2009). *M. aeruginosa* blooms have environmental and health consequences around the globe, resulting in increased anoxic events and the accumulation of the microcystin hepatotoxin in the water and the animals that come in contact with it. For the Indigenous people of the Klamath, the annual blooms occur during a ceremony season that requires human interaction with the river. To learn about these

1 The discovery of *M. aeruginosa* was a significant factor in the 2023/2024 removal of the Klamath River Dams. It will be interesting to see if harmful blooms of *M. aeruginosa* are detected in fall 2024.

issues, the impacted communities, and how understanding fundamental STEM principles can help to address this problem, Klamath Connection students engaged in a water quality laboratory alongside faculty, Indigenous scientists and cultural practitioners. The activity was woven through multiple co-curricular and curricular components of the Place-Based Learning Community (PBLC).

This study examines whether Klamath Connection students who learned about and/or related to the environmental, scientific, and social justice issues faced by the Native American communities of the Klamath River Basin show improvements in STEM retention and success. Our research was designed to explore three hypotheses:

1. Klamath Connection student participants who learn about Native American culture through the water quality laboratory will demonstrate intellectual growth, exhibit psychosocial factors associated with STEM retention, and show gains in academic achievement.
2. Klamath Connection student participants who see parallels between issues facing contemporary Native American communities and their home communities will demonstrate intellectual growth, exhibit psychosocial factors associated with STEM retention, and show gains in academic achievement.
3. Klamath Connection student participants who believe understanding cultural, social, and/or environmental justice issues of Native American people will help them in their future careers will demonstrate intellectual growth, exhibit psychosocial factors associated with STEM retention, and show gains in academic achievement.

FIGURE 1. Klamath Connection Students Explore the Science and Culture of the Karuk and Yurok People Through a Water Quality Laboratory (WQL)

A

B

A. In 2002, water quality scientists of the Karuk Tribe discovered levels of Microcystis aeruginosa in the reservoirs behind the Klamath dams nearly 100 times greater than the level approved by the World Health Organization. These blooms occur during the time of year that Karuk people are in and around the river gathering food, basketry materials, and performing ceremonies.
B. Klamath Connection students conducted a basic eutrophication experiment to see if nitrogen is the factor limiting harmful algal blooms downstream of the dams. Students sampled Klamath River water and analyzed their cultures for the presence of algae, using relative fluorescence units (RFUs) of their cultures and microscopy after adding ammonium nitrate (not shown).

Study Location

This project was performed at Cal Poly Humboldt (California State Polytechnic University, Humboldt, formally Humboldt State University), a mid-sized master's degree-granting state university located on the Pacific coast approximately 100 miles south of the Oregon border. The northernmost campus of the California State University (CSU) system, it is in a rural setting with a predominantly non-Hispanic white population (~73%, U.S. Census Bureau, 2021). The campus sits on the unceded territory of the Wiyot people and serves a local admissions and service area with over a dozen Native American communities, including the two largest federally recognized American Indian tribes in California (the Yurok Tribe and the Karuk Tribe). Due in part to a long history of campus-community partnerships, Cal Poly Humboldt has the largest number of American Indian students of the 23 CSU campuses (CSU Student Success Dashboard). Nonetheless, the percent enrollment of American Indian students (2–3%, CSU Dashboard) is lower than the regional population (11.2%, US Census 2020).

The Curriculum

We developed curricular and co-curricular activities that weave the science, societal issues, and cultural impacts of the harmful algal blooms (HABs) of toxic *M. aeruginosa* into first-semester STEM curricula (Figure 1).[2] The students conducted much of the experiment as part of the pre-semester summer experience (S1). After an introductory presentation and a conversation about cultural sensitivity (S2), the students joined faculty and peer mentors on a field trip to the Klamath River to learn from Karuk and Yurok experts about the watershed and the environmental, cultural, and social justice issues created by the HABs. The students then collected Klamath River water with guidance from Karuk water quality scientists and university faculty. When the students returned to campus, they performed a eutrophication experiment to monitor their samples for the presence of *M. aeruginosa*.

In the fall semester, students identified the algal species by microscopy in their botany course (S3), collected fluorescence data from the algal photosynthetic pigments in their first-year seminar course (S1), and analyzed the relative fluorescence units (RFUs) as a proxy for cellular abundance in their math course (S4). Karuk and Yurok scientists and cultural practitioners gave lectures in the critical thinking class to discuss the cultural and environmental reasons that the Tribe monitors, manages, and advocates for the health of the river. After a culminating lecture by all first-semester faculty linking the topic to each STEM course and its associated discipline (S5), students completed a final lab report (S1) and a reflective essay in a critical thinking course (see Design and Methods below). In the second semester, students continued to explore the topic in their Native American Studies class and through a chemistry laboratory (S6).

Design and Methods

This study involves the first three cohorts of Klamath Connection students (2015, 2016, and 2017). All data collection, management, and analysis were completed under approval of the campus's Institutional Review Board (IRB 14-013) to ensure protection of the rights and welfare of human subjects of research in accordance with the 1964 Helsinki guidelines.

Upon acceptance to the university, first-time first-year students who declared majors in biology, botany, environmental resources engineering, environmental science and management, fisheries, wildlife, or zoology received paper and electronic invitations to participate in Klamath Connection. These communications were followed by more personalized calls and emails from staff and faculty. Students who accepted the invitation began Klamath Connection pre-semester activities as soon as they arrived on campus as part of the pre-semester summer immersion experience. Once classes began, students were grouped into courses that filled their first-semester schedule: Introduction to Botany, Critical Thinking, Introduction to Math at the appropriate level, a first-year seminar, and another general education course. To facilitate block scheduling, the first cohort was comprised of students who entered the university math ready. Cohorts two and three were of all levels of math preparedness. In the second semester, all Klamath Connection students took a major-appropriate introductory chemistry course and Introduction to Native American Studies.

A survey was designed and administered to the 2016 and 2017 Klamath Connection cohorts in the third week of their spring semester Native American studies course (S7). The survey asked students 1) if the water quality laboratory and other activities were effective in increasing student's knowledge of Native American culture; 2) if the student saw parallels between issues facing contemporary Native American communities and issues in their home communities; and 3) if the student thought understanding issues faced by contemporary Native American communities would be helpful to their future career. The survey also contained a question that allowed students to self-identify their race and ethnicity by selecting all categories they identified with (American Indian, African American, Asian, Hispanic/Latino, Pacific Islander, Unknown, and/or White).[3]

2 Supplementary Information S1-S7 is available online.

3 We asked students to self-identify all categories of their race and ethnicity, because university data sorts students according to the Integrated Postsecondary Education Data System (IPEDS) protocol, which groups individuals reporting two or more ethnicities as either *Hispanic* (if one of the ethnicities is Hispanic) or *Two or More*.

To determine whether the student participants experienced intellectual growth and gains in psychosocial factors associated with first-year retention in STEM, we performed a thematic analysis of 241 reflective essays written by three cohorts of Klamath Connection students in the critical thinking course (62 in 2015; 85 in 2016; 94 in 2017). The reflective essay was written in response to this prompt given in the critical thinking course:

> Now that you have completed the water quality laboratory, worked with some of its data, and examined its design from a critically thinking scientist's perspective, think about your own intellectual growth over the semester. What did you think of the process back in the pre-semester experience? Do you think about it differently now, and how?
>
> What do you think about the role of foundational disciplines (e.g., math, botany, chemistry) in understanding complex environmental and social problems? Have those thoughts changed since you've arrived (on campus)?

The 2015 essays were analyzed by hand to identify initial codes (Sprowles). Using Atlas.ti, the codes of all 241 essays were refined and analyzed and sorted into themes (Smith). The codes and themes were reviewed and finalized by three members of our analysis team (Sprowles, Smith, and Johnson).

University-issued student identification numbers were used to identify students who completed both the essay and the survey. This allowed us to explore whether self-reported intellectual growth and gains in psychosocial behaviors associated with STEM retention coded in the essays were more common for students who reported learning about Native American culture through the water quality laboratory (WQL YES), saw parallels to their (your) home community (YOC YES) and/or believed that understanding cultural, social, and/or environmental justice issues of Native American people will help them in their future careers (HFC YES). The student respondents were subdivided based on their URG status. This resulted in four categories of respondents for each of the three hypotheses: Non-URG YES, URG YES, Non-URG NO and URG NO.

Academic achievement was assessed using retention and course success data obtained from the University's Office of Institutional Effectiveness. Retention was defined as the percentage of students returning for a second year or more in any major (= retention) or returning and still in a STEM major (= STEM retention). Student grades were used to calculate GPAs earned in STEM courses. Pass rates were calculated by categorizing A, B, C, or Credit as a "credit" and D, F, or unauthorized withdrawal as "no-credit." Students receiving an incomplete or withdrawing early were not included in these analyses.

Data analyses were conducted in R (R Core Team, 2018). The effect sizes are reported as Hedges' g (for continuous variables) or Cox's index (for binary responses) (WWC, 2017). We interpret small effects as Hedges' g and Cox's index value of 0.2–0.49, medium effects as values between 0.5 and 0.79, and large effects as values >0.8 (Cohen,1988).

Results

A total of 97 Klamath Connection students completed both the survey and reflective essay (Table 1). Sixty-four of the 97 students (66%) self-identified as belonging exclusively to a racial or ethnic group whose representation in STEM fields is similar to that group's percentage of the U.S. population (Non-URG: White and/or Asian American) (NCSES, 2021). The remaining 33 students (34%) self-identified as belonging to at least one racially minoritized group that is historically underrepresented in STEM (URG: African American, American Indian, Hispanic/Latinx, Native Alaskan, Native Hawaiian, and/or Pacific Islander) (Table 1).

Thirty percent of Non-URG students (19 out of 64) and 39% of URG students (13 of 33) reported they had learned about the issues faced by Native Americans living along the Klamath River through the water quality laboratory curriculum (WQL YES Non-URG and WQL YES URG, respectively) (Table 2). Quotes from the essay provide important insights.

In this first quote, *Student A* describes how exploring the toxic algal blooms from different perspectives illuminated the importance of understanding the social and cultural impacts of the *Microcystis* blooms on the Indigenous communities of the Klamath Basin:

TABLE 1. Participant Demographics

The Non-URG category includes groups whose representation in STEM fields is similar to that group's percentage of the U.S. population. The URG category includes minoritized groups historically underrepresented in STEM fields.

Race/Ethnicity IPEDS	Race Ethnicity Self Identified	n
URG (n=33)		
African American		2
Hispanic/Latino	Hispanic/Latino	18
	Hispanic/Latino, African American, White	1
	Hispanic/Latino, African American, American Indian, White	1
	Hispanic/Latino, American Indian	1
	Hispanic/Latino, Pacific Islander, Asian American	1
	Hispanic/Latino, White	7
Two or More	African American, American Indian, white	1
	Pacific Islander, Asian American,	1
Non-URG (n=64)		
White		56
Asian American		5
Two or More	Asian American, White	3
Total		97

TABLE 2. Percentage of Students Who Report That the Water Quality Laboratory Increased Their Knowledge of Native American Culture, See Relevance to Their Own Communities, and Believe the Information Has Prepared Them for Their Future Careers. Students subdivided by Non-URG and URG

	Non-URG n=64	URG n=33
Students who learned about Native American culture through the water quality laboratory (WCL)	30% (19)	39% (13)
Students who saw parallels between issues that affect Native American communities in their own communities (YOC)	37% (24)	55% (17)
Students who think information about issues that affect Native American communities better prepared them for their future career	86% (54)	81% (27)

> "As we began the experiment, the effect the algae would have on social issues had not even crossed my mind. I had viewed the damage of the increased algae as an environmental issue. … I had viewed the data for the health damages it could cause to humans as well as their animals, but never the cultural impacts. Searching the impacts of the algal bloom on surrounding cultures in the critical thinking class just added yet another layer to the problem that I had not seen yet—how the increased amounts of toxic algae made it impossible for these tribes to perform their annual ceremonies and how that affected their social and cultural well-being." – *Student A*

Student B describes how meaningful it was to have the opportunity to help address these issues:

> "Once I heard about the fish kill, the Tribes, and how devastating it was for them, I thought that just learning about the situation was helping in some small way. I was pleased when we might actually help understand things more clearly by performing our own experiment and gathering our own data." – *Student B*

Student C describes the importance of hearing directly from Indigenous scientists and how it broadened their perspectives:

> "(Initially) I looked at the outcome of the experiment as something that only needed to be said once and then forgotten rather than diving deeper into the issues at hand. Fortunately, this ignorance did not last. … After class discussions in the critical thinking class and a visit from two members of the Karuk Tribe Department of Natural Resources, I began to take the whole topic seriously. The guest speakers truly did spark interest for me because they applied spirituality to science in such a logical way. They did convince me that there is more to science, and you cannot completely rely on Western science or disregard the way other cultures 'carry out' science. Ultimately, my whole fixed perspective, which is in fact a logical fallacy, on the experiment was finally shifted." – *Student C*

There was also a higher percentage of URG students who identified parallels between issues that affect Native American communities and their own communities, with 17 YOC YES URG students (52%) and 24 YOC YES Non-URG (37.5%) (Table 2).

Student D draws parallels between the Klamath Indigenous communities and those in a National Park close to their home:

> "Both communities deal with the struggle of preserving resources and saving certain plant species as they face increasing numbers of tourists, litter, and carbon emissions within xxxx National Park, which multiple cultures have an agreement with to gain their resources." – *Student D*

Another student compared current efforts to protect a nature preserve to another topic discussed in the critical thinking course: the fight to stop the development of a U.S. Forest Service road that would connect the towns of Gasquet and Orleans (the G-O Road). The road would pass through high country sacred to the Karuk, Yurok, and Tolowa people (Emenhiser, 2005).

> "Back home, there is a conflict because the town may put a road through a nature preserve, and we are trying to get the town to take that road option off the table. Kind of similar to [the] threat to Native American lands for things like roads (G-O Road)." – *Student E*

Though the majority of free responses were related to environmental issues, some racial concerns were described:

> "How people of different beliefs and cultures may be viewed as wrong/different or unjust." – *Student F*

A strong majority of both URG and Non-URG students reported that the information they learned about issues that affect Native American communities has better prepared them for their future career (HFC URG YES 82% and HFC YES Non-URG 84%) (Table 2).

Some of these acknowledged that all lands have Indigenous history even if they are not controlled by Indigenous people:

> "So I know where I am, whose home I'm on, whether it is still 'their' land/home." – *Student G*

TABLE 3. Learning About Native American Culture through the Water Quality Laboratory and Seeing Parallels to Own Community Effects on Academic Behaviors and Psycho/Social Factors Associated with Student Persistence. Gains in essential learning outcomes were pronounced for URG students who also reported learning about Native American (NA) culture through the water quality laboratory (URG WQL YES). Seeing parallels (relevance) to their (your) own community (YOC YES) showed effects in all 8 categories for both URG and Non-URG students. Small Cox's index effects (0.2-0.49) are represented as*, medium (0.5-0.79) as **, and large as *** (values > 0.79) (Chen, Cohen, & Chen, 2010).

		WQL			YOC		
Themes		n Yes	% Yes	Cox's Index	n Yes	% Yes	Cox's Index
Intellectual Growth							
Critical Thinking Skills	Non-URG	8	50.0%	0.10	11	44.0%	-0.144
	URG	3	37.5%	-0.44	11	61.1%	0.43*
Gaining new knowledge/perspectives	Non-URG	14	87.5%	0.37*	21	84.0%	0.28*
	URG	7	87.5%	0.70**	15	83.3%	0.78**
Connecting social and environmental issues	Non-URG	12	75.0%	-0.14	21	84.0%	0.47*
	URG	7	87.5%	0.59**	14	77.8%	0.20*
Interdisciplinary/connectedness	Non-URG	10	62.5%	0.05	16	64.0%	0.20*
	URG	5	62.5%	0.06	12	66.7%	0.41*
Role of Foundational STEM Courses	Non-URG	12	75.0%	0.00	21	84.0%	0.63**
	URG	7	87.5%	0.81***	14	77.8%	0.57**
Psycho/Social Factors of STEM Success							
Connections with students/faculty	Non-URG	3	18.8%	-0.35	7	28.0%	-0.041
	URG	3	37.5%	0.26*	6	33.3%	0.36*
Helped with transition to university	Non-URG	2	12.5%	0.12	5	20.0%	1.3***
	URG	1	12.5%	0.03	3	16.7%	N/A
Intro to major/forming scientist identity	Non-URG	9	56.3%	0.00	17	68.0%	0.59**
	URG	5	62.5%	0.16	10	55.6%	-0.038

Others described the importance of humility, respect and relationship building:

> "It helped me realize it is important to know what tribes you are working with to not only respect their culture but to create strong connections." – *Student H*

> "I believe it will help me understand who I'm working with and ... how to best work with different communities." – *Student I*

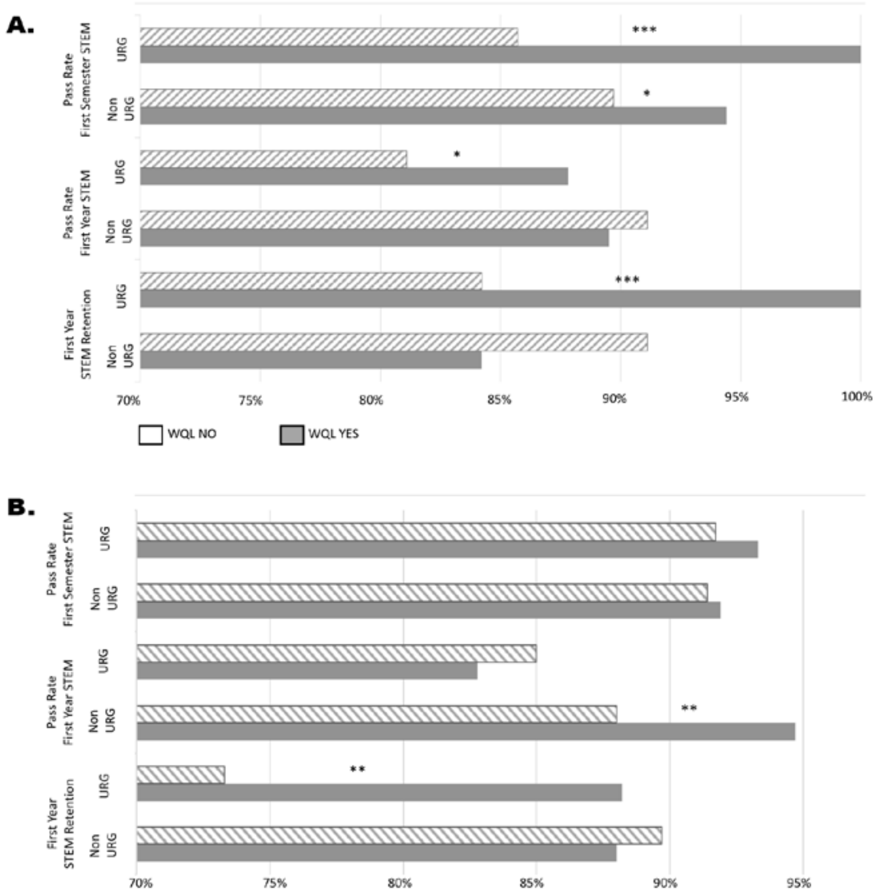
> "As a doctor, I (will) have to be culturally aware of my patients to treat them."–*Student J*

Though these comments were meaningful, the small proportion (<20%) of HFC NO students prohibited examining the impact of this on additional student outcomes.

The thematic analysis of the reflective essays produced eight themes (Table 3). Five were indicative of intellectual growth: *gaining new knowledge and perspectives*, *connecting social and environmental issues*, *relevance of STEM foundational courses to social and environmental issues*, *interdisciplinary connectedness*, and *critical thinking* (Association of American Colleges and Universities, 2007). Three themes were psychosocial factors associated with college success and academic achievement: *connections to staff and faculty* (Astin, 1993), *assisting with transition to university* (Hurtado and Carter, 1997), and *forming a scientist identity* (Trujillo and Tanner, 2014).

A higher percentage of students who reported learning about Native American issues in the water quality laboratory (WQL YES) reported gains in *new knowledge and perspectives* than those who did not (WQL NO). Only

FIGURE 2. Klamath Connection Students Explore the Science and Culture of the Karuk and Yurok People Through a Water Quality Laboratory (WQL)



A. Impact of Learning about Native American Culture through the Water Quality Laboratory.

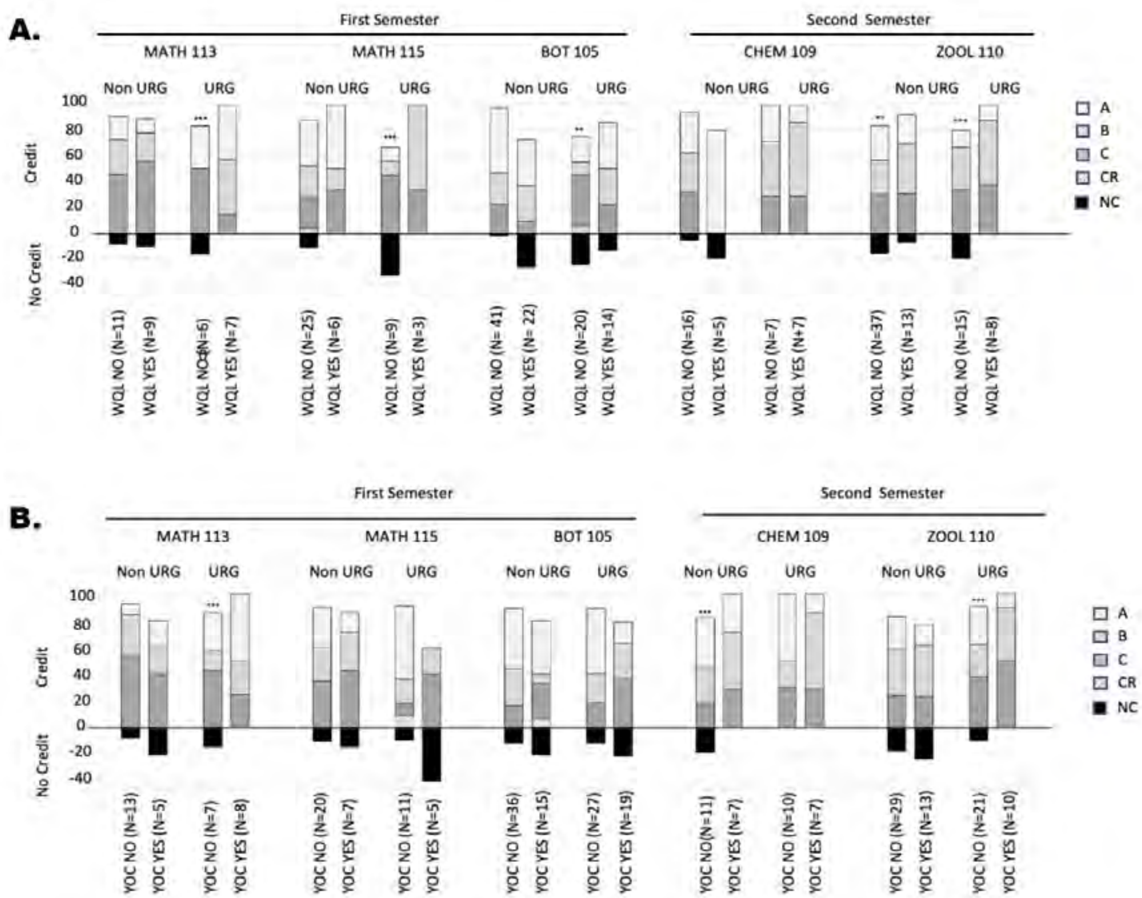
B. Seeing Parallels Between Issues Facing Native American People and Their Own Community on First-Semester STEM Pass Rates, First-Year STEM Pass Rates and Retention into the Second Year

Cox's g. * = small effect, ** = medium effect, *** = large effect.

a small effect differentiated the WCL YES Non-URG students from WCL NO Non-URG, whereas the effect was medium for URG students. A higher percentage of WCL YES URG students also reported *connecting social and environmental issues* (medium effect size), seeing the role of core STEM classes in understanding these issues (*role of foundational STEM courses*, large effect size), and *making connections with students and faculty* (small effect).

Students who saw parallels between issues faced by Native American communities and their own communities (YOC YES) also had a higher percentage of comments associated with the themes than those who did not (YOC NO). Both URG and non-URG YOC YES students reported gains in *connecting social and environmental issues* and *interdisciplinary connectedness* (small effects), and gains in *understanding the role of foundational STEM courses* (medium effect). The YOC YES URG students also reported gains in *critical thinking*, and *connections with students and faculty* (small effects) and in *new knowledge/perspectives* and *role of foundational STEM courses* (medium effects). YOC YES Non-URG had the most gains of any group, with additional gains in *new knowledge and perspectives;* in *role of foundational STEM courses;* and in *forming scientist identity*. They were the only group to show an increase in the percentage of

FIGURE 3. Pass Rates and Grade Distributions in First-Year STEM Bottleneck Courses for URG and Non-URG Students Who A) Learned about Native American Culture Through the Water Quality Lab (WQL YES) and B) Saw Parallels Between Issues Faced by Native Americans and Their Own Communities (YOC YES). Cox's g. * = small effect, ** = medium effect, *** = large effect.



students reporting a gain in *helped with transition to the university* (large effect).

To examine gains in STEM persistence and academic achievement, we began by exploring first-semester and first-year STEM pass rates and first-year STEM retention. All WCL YES students had higher semester STEM pass rates than WCL NO students, but only WCL YES URG students had increased first-year STEM pass rates and first-year STEM retention (Figure 2A).

There were two increases in persistence and achievement seen for YOC YES students. Non-URG YOC YES students had a medium increase in first-year STEM pass rates and URG YOC YES students had a medium increase in first-year STEM retention (Figure 2B).

Next, we explored the individual pass rates of first-year STEM bottleneck courses (Figure 3). WQL YES students had higher pass rates in all of their first-year STEM bottleneck courses, with four having Cox's g effect sizes of medium to high. YOC YES URG students had gains in the first-semester pass rate of their college algebra course (MATH 113 URG). In the second semester, CHEM 109 YOC YES Non-URG students and Introductory Zoology (ZOOL 110) YOC YES URG students had improved pass rates.

Finally, we explored the impacts of our program on first- and fourth-year overall GPAs, units earned, and STEM GPAs (Table 4). There was a medium effect of learning about Native American issues through the water quality laboratory (WQL YES) for URG students in first-year overall GPA (3.23 vs. 2.86) and fourth-year overall GPA (3.19 vs. 2.97). There was a large effect of WQL YES for URG students on average first-semester STEM GPA (3.31 vs. 2.33) and small effects on average first-year STEM GPA (2.89 vs 2.58), and on first attempt

TABLE 4. Impact of Learning about Native American Culture Through the Water Quality Laboratory (WQL) and Seeing Parallels to Issues Faced by Native Americans to Own Communities (YOC) on GPAs and Retention. Hedges' g interpretation of effect is *small (0.2-0.49), **medium (0.5-0.79), and ***large (>0.79) (Chen, Cohen, and Chen 2010).

	WQL							YOC						
	Yes	mean	SE	No	mean	SE	Hedges' g	Yes	mean	SE	No	mean	SE	Hedges' g
First Year														
GPA														
Non-URG	n=19	2.97	0.19	n=45	3.19	0.099	-0.3	n=25	3.21	0.14	n=39	3.07	0.117	0.2*
URG	n=13	3.23	0.14	n=19	2.86	0.186	0.51**	n=17	3.07	0.12	n=15	2.94	0.24	0.18
Units Earned														
Non-URG	n=19	39	3.89	n=45	44.67	2.261	-0.36	n=25	47.2	3.14	n=39	40.28	2.45	0.44*
URG	n=13	41.08	2.53	n=19	38.74	4.035	0.15	n=17	38	2.45	n=15	41.6	4.819	-0.24
Fourtth Year														
GPA														
Non-URG	n=19	3.23	0.15	n=45	3.28	0.075	-0.08	n=25	3.26	0.12	n=39	3.26	0.085	-0.01
URG	n=13	3.19	0.12	n=19	2.97	0.1	0.51**	n=17	3.07	0.11	n=15	3.11	0.108	-0.09
Units Earned														
Non-URG	n=19	39	3.89	n=45	44.67	2.261	-0.36	n=25	47.2	3.14	n=39	40.28	2.474	0.44*
URG	n=13	41.08	2.52	n=19	38.74	4.035	0.15	n=17	38	2.45	n=15	41.6	4.819	-0.24
STEM GPA														
1st semester														
Non-URG	n=18	2.72	0.27	n=39	2.58	0.18	0.12	n=22	2.76	0.26	n=35	2.53	0.18	0.2*
URG	n=13	3.31	0.2	n=14	2.33	0.265	1.15***	n=15	2.95	0.32	n=12	2.61	0.233	0.35*
1st year														
Non-URG	n=19	2.69	0.26	n=45	2.83	0.136	-0.15	n=25	2.92	0.18	n=39	2.7	0.163	0.22*
URG	n=13	2.89	0.25	n=19	2.58	0.224	0.32*	n=17	2.74	0.22	n=15	2.66	0.27	0.08
1st attempt STEM Bottleneck														
Non-URG	n=19	2.4	0.26	n=45	2.64	0.138	-0.23	n=25	2.63	0.21	n=39	2.53	0.155	0.09
URG	n=13	2.54	0.26	n=19	2.25	0.239	0.29*	n=17	2.29	0.2	n=15	2.45	0.303	-0.17

bottleneck classes (2.54 vs. 2.25). There were no meaningful effects for Non-URG students on these metrics.

Fewer gains in GPA were evident for students who reported seeing parallels with their own communities (YOC YES). There was a small impact on first-semester STEM GPA for both YOC YES URG (2.95 vs 2.61) and YOC YES Non-URG (2.76 vs. 2.53) students. YOC YES Non-URG students also had small gains in first-year overall GPA (3.21 vs. 3.07), average first-year units earned (47.2 vs. 40.28), and first-year STEM GPA (2.92 vs. 2.70).

Discussion

Our study demonstrates that weaving Indigenous science, culture, and social justice concerns into first-year STEM curricula can engage and inspire students to overcome barriers to STEM retention and improve academic outcomes. Our first two hypotheses were supported, but in different ways. Students who learned about Native American culture through the water quality laboratory (WCL YES) had gains in intellectual growth, psychosocial factors associated with STEM retention, and academic achievement. The greatest impacts were seen in STEM retention and academic achievement for WCL YES URG students, with improvements in first-year STEM pass rates, retention, and improvements in overall GPA and STEM GPAs by half a letter grade. This result supports the work of others who have demonstrated that including social context in STEM education can improve academic outcomes when students identify relationships between STEM curricula and diverse cultural perspectives (Estrada et al., 2011), altruistic goals (Lee, 2014), and/or empathy and equity matters (McGee & Bentley, 2017).

The students who saw parallels between issues faced by Native American communities and their own communities also had gains in intellectual growth and psychosocial factors, but they were predominantly observed in YOC YES Non-URG students. With the extensive literature supporting the influence of students' home communities on their collegiate success (Mishra, 2020), we anticipated a greater impact for the YOC YES URG students. It is curious that when asked to describe the similarities between issues faced by Native American communities of the Klamath Basin and their own community, only one YOC YES student highlighted family values. All the other YOC YES students highlighted parallels in environmental and social justice concerns. It would be interesting to know how many of these students come from communities that value this educational approach. Perhaps our students would find the programming more relatable if we incorporated urban values, something that has historically been challenging for place-based programs grounded in eco-literacy and outdoor education. (Shannon & Galle, 2017).

Since more than 80% of the students in this study believed understanding Native American communities will be important to their future careers, we were not able to evaluate our third hypothesis. We do know that these same cohorts of Klamath Connection students have increased first-year retention and graduation rates when compared to non-Klamath Connection students with the same majors (Johnson et al., 2020, 2023). College student motivation is directly linked to student retention (Graham et al., 2013), which can be increased by understanding post-graduate job prospects (Reardon et al., 2015) and financial security (Próspero & Vohra-Gupta, 2007). It would be interesting to explore whether identifying broader STEM career possibilities impacts intellectual growth, retention, and/or academic achievement, using PBLC participation as the variable.

We believe ours is one of the first studies to specifically examine the power of creating curriculum that highlights scientific, cultural, and social justice concerns of Indigenous communities and how a curriculum of this kind might improve outcomes for first-year URG college STEM students. Though we are encouraged by our results, we hesitate to draw expansive conclusions due to the small sample size of our study and the opt-in nature of the initial iterations of Klamath Connection. Cal Poly Humboldt is in the process of launching place-based learning communities for all first-year students. This will allow us to see if similar outcomes are observed when more students participate in activities co-created with the Indigenous communities of our area. We will also evaluate the impact of this approach on students who were not given the choice to participate in a learning community.

It is important to note that there were 52% fewer URG students than non-URG in this study. Of the URG, only three self-identified as American Indian (Table 1). If we are going to continue place-based learning communities, it is essential that they serve the people of our region. Aikenhead (2006, pp. 107–108) stated that "culture-based clashes occur in science classrooms for students whose worldviews and cultures (including their home language) differ from those of Western science conveyed by school science." This can be exacerbated when place-based educators promote a colonized educational environment by excluding critical interrogation and introspection about how place intersects with race, gender, and colonialism (Shannon & Galle, 2017). As we expand place-based learning communities, we will strive to create culturally responsive programming that not only incorporates the values, perspectives, and cultures of our region, but also creates an educational environment that attracts and empowers Native American students.

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Data Availability Statement. The datasets generated during and/or analyzed during the current study are not publicly available, because the privacy of the individual participants could be compromised. They are available from the corresponding author on reasonable request.

About the Authors

Amy Sprowles is a fourth-generation educator. She is an associate professor of biological sciences at Cal Poly Humboldt and Director of the Humboldt CIRM Bridges Program and is Faculty Representative for two California State University initiatives in STEM education: CSUPERB and STEM NET. Dr. Sprowles is an 'IKE Alliance Founding Member, SENCER Ambassador, was the director of the Humboldt INCLUDES Planning Grant, and is a guest editor of this special edition. She has also served the University as Faculty Associate Dean of Undergraduate and Graduate Studies and Department Chair. At the time of this study, she served as Co-Principal Investigator; Co-Principal Investigator and Co-Director of the CSU STEM Collaboratives Award and the Cal Poly Humboldt DHSI STEM Grant; Director of the Cal Poly Humboldt HHMI Inclusive Excellence Award; and Principal Investigator and Director of the Humboldt Transcending Barriers to Success grant. She co-developed and co-taught the Klamath Connection critical thinking course, helped develop the survey (S7), led the design and authorship of the water quality laboratory, and taught all components (S1), was a co-presenter of S5, led and coordinated this research project, conducted the survey and essay coding, and is the primary author of this article.

Steven Margell served as Assessment Coordinator for the Cal Poly Humboldt DHSI STEM and HHMI Inclusive Excellence grants at the time of this study. He performed the descriptive data analysis. He is currently an analyst with the Cal Poly Humboldt Office of Institutional Research and Analytic Reporting.

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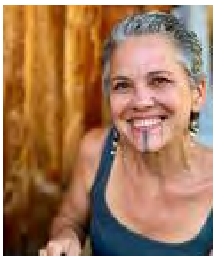

Lisa Morehead-Hillman (enrolled Karuk) is the founder of the Karuk Tribe's Pikyav Field Institute and author of multiple publications, including the cultural sensitivity document (S2) used in this study. The Klamath Connection students benefited from her guest lectures, as well as the overarching tribal guidance of the program.

L. Chook Chook Hillman is a Karuk Indian, Indigenous scientist, cultural practitioner, and educator. He taught best practices in water quality sampling to faculty and students at the Klamath River. He co-authored S1 and gave guest lectures to Klamath Connection students.

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Sonja Manor is an experienced mathematics educator who currently serves as a lecturer at Cal Poly Humboldt. As Place-Based Math Coordinator at Cal Poly Humboldt, she has worked with faculty from across the University to develop the interdisciplinary mathematics curriculum for incoming STEM students. These projects include revising the Klamath River algal growth labs, authoring a Humboldt Bay Sea Level Rise modeling activity that incorporates local geology, and creating an ocean acidification lab which uses local pH data and compares the Humboldt Bay estuarine environment to nearby open coastal systems. These interdisciplinary units are central to the integrated place-based curriculum at Cal Poly Humboldt. Ms. Manor recently completed an ESCALA certificate in teaching and learning for Hispanic-Serving Institutions and has focused her 20-year teaching career on making mathematics meaningful and interesting with applications. She believes that students are more motivated when their courses feel relevant and connected to other disciplines. She served as one of the Klamath Connection mathematics instructors, was a co-author of S4, and a co-presenter of S5.

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Alison O'Dowd earned her BS in environmental science from the University of Oregon and her PhD in aquatic ecology from UC Berkeley. She is a professor and Chair of the Department of Environmental Science and Management at Cal Poly Humboldt and the Co-Director of Cal Poly Humboldt's River Institute. Her research interests are in the fields of aquatic ecology and ecological restoration. More recently, her research has explored the impacts of dams and dam removal on downstream ecosystems in the Klamath, Trinity, and Eel Rivers. She assisted students during the Klamath field trip, helped them collect fluorescent data, and helped students synthesize the linked curricula in the first-year experience course.

P. Dawn Goley earned her PhD at the University of California, Santa Cruz, studying the behavioral ecology of Pacific white-sided dolphins. She began teaching and conducting marine mammal research in the Department of Biological Sciences at Cal Poly Humboldt in 1996. Undergraduate and graduate students have gained valuable research experience in her Marine Mammal Education and Research Program through long-term studies of the behavioral ecology of gray whales, Steller sea lions, harbor seals, and elephant seals, as well as by studying stranded marine mammals. Dr. Goley was a founding member of Klamath Connection, assisting students during the Klamath field trip. She helped them collect fluorescent data and helped students synthesize the linked curricula in the first-year experience course. She went on to be a leader in the design of Rising Tides and Among Giants Place-Based Learning Communities (PBLCs) in the College of Natural Resources and Sciences and helped develop the course Science 100: Becoming a STEM Scientist in the 21st Century for each of these PBLCs.

Gillian Black is a lecturer and academic advisor at Cal Poly Humboldt for first- and second-year STEM students (particularly PBLC/Klamath Connection students). She assisted students during the Klamath field trip, helped them collect fluorescent data, and helped students synthesize the linked curricula in the first-year experience course.

Katlin R. Goldenberg is the Director of Place-Based Learning Communities (PBLCs) at Cal Poly Humboldt. She has spent the past nine years expanding and institutionalizing a unique and integrated approach to learning communities, enabled by her ability to build initiatives that support broadscale guided enrollment across campus and create a collaborative and integrated welcome experience. Because of these efforts, and the efforts of exceptional working groups of dedicated faculty and staff, there are now 15 total PBLCs with capacity to support all first-time first-year students on campus. She coordinated the implementation of the water quality laboratory and created the block scheduling.

Matthew D. Johnson is a professor of wildlife habitat ecology at Cal Poly Humboldt, where he has taught since 1999. He earned a BS in wildlife at UC Davis and a PhD in ecology at Tulane University. His interests are in wildlife habitat ecology, with a particular focus on wildlife in agricultural areas and other working landscapes. His goal as an educator is to provide opportunities for a diversity of students to learn the skills that will empower them to contribute to a just and sustainable society, while also fostering an appreciation for how good land management practices can benefit both people and nature. As a researcher, his goal is to answer ecological questions that offer practical information for farmers to simultaneously advance their own goals and also help wildlife. Matt served as the Principal Investigator and Director of the CSU STEM Collaboratives Grant and the Cal Poly Humboldt DHSI STEM Grant [#P031C150193] and the Principal Investigator and Co-Director of the Cal Poly Humboldt HHMI Inclusive Excellence Award [52008703]. As the Klamath Connection Faculty Coordinator, he participated in all aspects of the curricular and co-curricular development, the experimental design, and qualitative and descriptive data analysis, and performed critical input on each draft of the manuscript. He was also a co-instructor of the Klamath Connection critical thinking course.