Exploring Science Identity and Latent Factors of Student Gains in a Place-based Marine Science CURE Designed to Provide Access to Hawaiʻi Students from Historically Marginalized Ethnicities

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ABSTRACT

Hawaiʻi students, and in particular Native Hawaiian students, face high rates of attrition and low representation in Science, Technology, Engineering, and Mathematics (STEM) academic majors and careers, but place-based Course-based Undergraduate Research Experiences (CUREs) such as the Research Experiences in Marine Science (REMS) summer program may help to better engage these students with scientific content understanding and skills development. This article assesses latent factors of student gains after participating in the REMS program as they relate to student science identity. Results from an exploratory factor analysis examining the internal structure of an assessment measure delivered during the program suggest strong evidence of four latent factors in student self-reported learning gains: Content Understanding, Scientific Skills, Interest, and Integration. These factors will guide the development and delivery of the REMS survey as it is applied to additional cohorts of students participating in REMS and other, similar programs being developed and implemented in Hawaiʻi to support Native Hawaiian students. Although there were no significant relationships between these factors and responses to a science identity survey item, additional insights from an alumna of the program highlight how place-based elements in CUREs provide authentic and rigorous research training experiences for students from populations historically marginalized in STEM.

INTRODUCTION

A Science, Technology, Engineeing, and Mathematics (STEM) workforce that fuels new scientific discoveries and equips our nation to better combat the twin global crises of climate change and biodiversity loss is growing. Over the last 10 years, the U.S. workforce has increased such that nearly one-fourth of the population is employed in STEM-related jobs overall. However, accompanying STEM professional diversity over this timeframe has seen relatively gradual gains (National Center for Science and Engineering Statistics [NCSES], 2023). Disparities continue to persist among women, individuals with disabilities, and among certain ethnic and racial minorities. Such racial and ethnic imbalances widen with higher degree levels, where 82% of skilled STEM occupations require at least a Bachelor's degree, and with disparities that also vary among ethnicities and degree types (NCSES, 2023). In marine- and ocean-related STEM fields for example, while there is very limited information regarding current workforce diversity, generally acknowledged inequities triggered by long standing and systematic exclusion and biases has resulted in a highly disproportionate lack of diversity in marine-related disciplines (Johri *et al.*, 2021). Sexism,

James Hewlett, *Monitoring Editor*

Submitted Feb 1, 2024; Revised Jul 22, 2024; Accepted Sep 17, 2024

CBE Life Sci Educ December 1, 2024 23:ar50

DOI:10.1187/cbe.24-02-0038

Conflicts of interest: The authors declare no conflicts of interest.

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racism, power disparities among groups of students, lack of access to foundational education or qualified teachers, lack of representation of diverse faculty, or rising tuition prices are symptoms of enduring legacies of colonialism and imperialism and structural barriers that exclude other world views, which together make STEM education a difficult path to pursue among historically marginalized groups, including Native Hawaiians and Pacific Islanders (Pierszalowski and Bouwma-Gearhart, 2018; Kane *et al.*, 2023).

While ethnic diversity collectively speaking has seen modest increases since 2011 (up 6% in the last decade), most of this rise is attributed to a rise of Hispanic professionals in STEM fields, followed by African Americans, with relatively small contributions from Indigenous ethnic groups including American Indians, Alaska Natives, and Native Hawaiians and Other Pacific Islanders (collectively, NHPI). NHPI is such a small minority group in the STEM research community that "data are not always presented in detail due to numerical constraints" (pg. 31, NCEAS 2023). Thus, information on NHPI in the STEM fields has been sparse, and characterization of these groups, particularly in any one discipline such as marine science, is fraught with uncertainties due to relatively little data (e.g., In 2018, only one of the 619 Earth, Atmospheric, and Ocean Sciences doctorates given to U.S. citizens and permanent residents in the United States was awarded to a Native Hawaiian [NCSES, 2021]). However, it is generally acknowledged that NHPIs are severely minoritized in STEM and especially within the marine and ocean sciences.

University of Hawaiʻi at Mānoa as a Native Hawaiian Place of Learning and a Truth and Racial Healing Campus

The University of Hawaiʻi (UH) system of campuses includes seven community colleges and three universities and hosts an array of ethnic and racial diversity that mirrors that of the State of Hawaiʻi, having among the highest cultural, ethnic, and racial diversity in the country (US Census Bureau, 2021). Collectively, these campuses host nearly 22.6% NHPI students (University of Hawaiʻi, 2023), slightly more than the next largest racial grouping (Caucasians at 22.1%). Among the faculty however, while 42% are Caucasian, just 17% NHPI are represented (University of Hawaiʻi, 2022), consistent with the premise that NHPI are severely minoritized in the academy overall, particularly in STEM. Indeed, despite the potential for the university to create robust pathways for NHPI students in STEM, these ethnic groups have experienced persistent underrepresentation in the UH STEM colleges (Kane *et al.*, 2023). Although numerous new UH programs have recently emerged in this realm, there continues to be a pressing need to create more and better opportunities that enhance the inclusivity of ocean STEM education and professional pathways, fostering local workforce development across the diverse communities of Hawaiʻi.

To do so, the unique student population in Hawaiʻi deserves educational experiences that not only emphasize scientific inquiry, but also acknowledge, honor, and integrate different ways of knowing rooted in the Indigenous host culture and local communities that have historically been marginalized (Rivera *et al.*, 2022). The University of Hawaiʻi at Mānoa's (UHM) recent strategic plan (*Mānoa 2025: Our Kuleana to Hawaiʻi and the World*, 2015), aligning itself with the state's Indigenous culture, underscores its commitment to being a student-centered, Carnegie Research 1 institution that serves the community and is grounded in Native Hawaiian traditions of learning. The strategic framework consists of four high-level goals that include becoming a Native Hawaiian Place of Learning (NHPoL), Student Success, Sustainability, and Research Excellence, all anchored at its core in principles of aloha ʻāina (a recognition, commitment, and practice to sustain the life breath between people and the natural environment that resulted in hundreds of years of sustainable care for Hawaiʻi before colonization) (Figure 1). This approach not only embraces the diversity of Hawaiʻi, but also respects and values the wealth of knowledge passed down through generations by Native Hawaiians as the host culture of the islands.

In 2018, a new office was created to support UHM's strategic priority of becoming a NHPoL. The NHPoL Advancement Office's work is organized under three "pathways" that help foster a rooted, resilient, and responsive community. The ideas of Aʻo (learning from one another), Alu (connecting with each other), and ʻAuamoa (working together), combined with the designation as a Truth in Racial Healing (TRHT) campus with its foundational pillars of narrative change and racial healing, provide a framework for programs that work toward achieving a vision for Hawaiʻi to recognize interdependent kuleana (responsibility) and aloha, and aloha ʻāina (Lipe *et al.*, 2020).

A number of culturally grounded programs at UHM have emerged over the last ~18 years that embrace these frameworks and are designed to increase access and facilitate persistence in geosciences, including in the marine and ocean sciences (reviewed in Kane *et al.*, 2023). Although many of these programs predate the current UHM strategic plan, they are very much anchored in the tenets of a Hawaiian sense of place and indeed some may have even influenced elements of the development of the strategic plan itself.

As the vast majority, if not all, of these programs have been extramurally funded, several have lapsed, while others struggle to persist. For example, the Research Experiences in Marine Science (REMS) Program is an "early-admit", entry-level, course-based undergraduate research experience (CURE) (which serves as the context of this study) that utilizes the expertise of Hawaiʻi-based marine science researchers whose specialties demonstrate how human impacts and global change affect coral reef ecosystems. It incorporates important concepts of Hawaiian sense of place, including various cultural, historical, and ecological resources available via surrounding community partnerships and within the larger university system (Rivera *et al.*, 2022). The program also utilizes factors recommended for undergraduate retention in STEM including broadening access, multi-tiered mentoring, increased recognition of diverse scholars, and authentic field and lab experiences (Fisher *et al.*, 2019; Johri *et al.*, 2021). As a bridge program, it is designed to facilitate transitions into college pathways in the marine sciences through scientific skills development and nurturing science identity along transitions from high school to early college and beyond (Ambrosino and Rivera, 2022, 2023).

Programs, like REMS, that deliver content grounded in inclusive frameworks are so important because student experiences in a STEM learning environment (which includes course content, social interactions amongst participants, and

FIGURE 1. Model adapted from Mānoa 2025 (Mānoa 2025: Our Kuleana to Hawaiʻi and the World Strategic Plan 2015-2025, 2019) illustrating four high-level goals presented as part of UHM's strategic plan to become a NHPoL, Student Success, Sustainability, and Research Excellence.

elements of the physical space) play a large role in influencing student interest and participation in science (Cheryan *et al.*, 2009; Ramsey *et al.*, 2013). One of the driving factors for the historical marginalization of some student groups in STEM fields may be the dissimilarities between their lived experiences and the culture of the science classroom or the science community. Pedagogical approaches that draw upon local cultures, histories, languages, and ecologies may increase student engagement with science content through engagement with and nurturing of a student's identity (van Eijck and Roth, 2009; Kuwahara, 2013; Ambrosino and Rivera, 2022).

Developing a positive science identity and sense of belonging to the science community may be a fundamental mechanism for increasing student persistence in STEM, especially among historically marginalized student groups (Chang *et al.*, 2011; Estrada *et al.*, 2011, 2018; Graham *et al.*, 2013; Byars-Winston *et al.*, 2016; Flowers and Banda, 2016). Science identity is a strong predictor of students' choices related to science pathways (Sumabat Estrada, 2020; Chen *et al.*, 2021). As a predictor of persistence in science, identity operates independently from other attitudinal factors concerning students' experiences within science communities and uniquely contributes to our understanding of their decisions (Vincent-Ruz and Schunn, 2018). Previous studies have explored the impact REMS, as a unique, place-based research training program for early-college students, may have on participant cognitive constructs related to identity (Ambrosino and Rivera, 2022) and conceptualizations of a "person of science" (Ambrosino and Rivera, 2023).

Addressing global challenges affecting ocean systems demands that researchers, resource managers, and policy developers possess a diverse set of social skills—such as communication, self-reflection, and empathy—alongside a solid grasp of scientific concepts and practices. This study aimed to build on previous research that examined student experiences in place-based, undergraduate research courses by assessing latent factors of student gains before and after participating in the REMS program. Specifically, it sought to understand how these factors correlate with constructs related to the development of science identity. The objectives were to explore students' self-assessment of their learning through the REMS program, investigate whether latent factors of student learning gains are related to self-reported science identity, and describe how these factors influence and contribute to creating an undergraduate research experience within a NHPoL.

MATERIALS AND METHODS

Intervention

For each year between 2013 and 2023, separate cohorts of students participated in an immersive, summer marine science research program (REMS) hosted by the Hawaiʻi Institute of Marine Biology (HIMB) in Kāneʻohe Bay, Hawaiʻi (for detailed description of institutional and curricular context, see Rivera *et al.*, 2022). The program is designed as a 4-credit, place-based CURE in marine science that draws upon Native Hawaiian epistemologies and knowledge and immerses participants in the HIMB research community. CURE-type programs are delivered within a framework that can make research communities more inclusive and are demonstrated to positively impact student performance, persistence, and sense of belonging in STEM fields (Auchincloss *et al.*, 2014; Corwin *et al.*, 2015; Rodenbusch *et al.*, 2016; Martin, 2021; Buchanan and Fisher, 2022; Rivera *et al.*, 2022). As a CURE, the REMS program integrates students into a professional research community that focuses on how human impacts and global change affect coral reef ecosystems. Each cohort consisted of 16 to 22 students, including a mix of high school students and recent high school graduates. A multi-tiered mentoring framework is developed each year among the incoming students, near-peer alumni mentors, undergraduate interns, graduate students, and early career professionals—an approach shown to facilitate development of science identity among both mentee and mentor students (Trujillo *et al.*, 2015; Atkins *et al.*, 2020) and creates a learning community that helps to retain students in STEM through a "persistence framework" (Graham *et al.*, 2013). Over the course of the program, students participated in course, field, and laboratory-based marine science activities, culminating in a student-led, small-group research project in collaboration with professional research scientists and peers.

Data Collection

We surveyed students at the beginning and end of the program to assess their gains in confidence, attitudes, and interest in marine science using an instrument designed on the Student Assessment of Learning Gains (SALG) platform (Seymour *et al.*, 2000) and through a protocol approved by the University of Hawai'i Institutional Review Board (protocol #2019-00605). The survey items included a combination of multiple-choice, Likert-type questions and open-ended, short-answer questions. Specific multiple-choice questions used for this analysis are described in the following sections. We included data from 2013 through 2018 ($n = 103$ for presurveys and $n = 105$ for postsurveys). We excluded 2019 because the program curriculum changed to an advanced version of REMS for program alumni enrolled in undergraduate programs. We excluded 2020–2022 due to curriculum modification necessitated by the COVID pandemic. In 2023, a new item was added to explicitly measure student self-assessment of science identity, and data from this identity measure were used to compare with the factors elicited from the structural analysis ($n = 22$).

Measures

Across years, items included on the presurveys and postsurveys varied and included both open-response and closed-response items. Our analysis here is focused on a core set of 16 closed-response items that were retained in the same form across all surveys. Table 1 includes the list of 16 closed-response student self-assessment questions, along with their abbreviations, that were considered for this analysis. The closed-response questions used a 5-point scale of agreement (1 = not at all; 2 = just a little; 3 = somewhat; 4 = a lot; 5 = a great deal).

TABLE 1. List of 16 Likert-scale student self-assessment questions, along with their abbreviations

Question (Item)	Abbreviation
Presently, I am interested in taking or planning to pursue a career in marine science.	Career
Presently, I am confident that I can use the scientific process to execute a research project.	Confident research
Presently, I am confident that I understand marine science.	Confident understanding
Presently, I am interested in discussing marine science with friends or family.	Discussing
Presently, I am enthusiastic about marine science.	Enthusiastic
Presently, I am willing to work with others to accomplish a research project.	Willing with others
Presently, I am in the habit of applying what I learn in classes to other situations.	Applying knowledge
Presently, I am in the habit of connecting key ideas I learn in my classes with other knowledge.	Connecting knowledge
Presently, I can use the scientific process to ask a question and develop a hypothesis.	Develop H0
Presently, I can develop an experiment to test a hypothesis.	Test H0
Presently, I can analyze and interpret experimental data to evaluate a hypothesis	Evaluate H0
Presently, I can work effectively with others.	Effective with others
Presently, I understand the ecology of coral reefs.	Ecology
Presently, I understand the effects of water quality on the fertilization processes of marine organisms, particularly sea urchins.	Fertilization
Presently, I understand how ideas we will explore in this class relate to your own everyday life.	Relate to life
Presently, I understand the scientific process.	Scientific process

Data Analysis

We explored the internal structure of the REMS survey instrument using exploratory factor analysis (EFA) on data from the presurvey. We then used Welch two-sample t tests to compare pre versus post mean values for each of the four latent factors identified by the EFA.

All data analyses were performed in R version 4.2.1 (R Core Team, 2022), using the psych package (Revelle, 2018) for visual scree plot (VSP), parallel analysis, and EFA. All programming code used for this analysis can be found at https://github.com/kdgorospe/REMS-SALG

Exploratory Data Analysis. We calculated descriptive statistics for each of the 16 items to assess whether assumptions of normality were severely violated (Curran *et al.*, 1996). We also explored whether any latent factors might exist by conducting Bartlett's test of sphericity and Kaiser, Meyer, Olkin (KMO) measure of sampling adequacy (Howard, 2016). In addition, data visualizations, such as correlation plots and histograms, were created.

EFA. We conducted EFA to examine the internal structure of the measure using only data from the presurveys. First, we assessed the potential number of latent factors by examining a scree plot and conducting parallel analysis. Parallel analysis is a method that compares the eigenvalue of each factor and the corresponding eigenvalue calculated for randomized simulated datasets of identical size. The reasoning behind this method is that eigenvalues from a randomized dataset represent statistical artifacts, so only factors that provide more explanatory value than random should be retained for EFA (Horn, 1965; Hayton *et al.*, 2004).

We then estimated and examined EFA models for each potential number of latent factors indicated by parallel analysis. All EFA models used a promax (oblique) rotation to permit intercorrelation between the latent factors (Fabrigar *et al.*, 1999). We examined the results of each EFA model and selected the model that was most coherent and interpretable.

Science Identity Measure. There was an additional identity item included for the 2023 REMS surveys in which students rated their agreement with the statement: "I am a scientist" (on a scale of 1 to 5; 1 = disagree, and 5 = strongly agree). Responses were collected from 21 students on the first day of the program (preprogram) and 15 students on the final day of the program (postprogram). Preprogram and postprogram results were compared with a Mann–Whitney U test to determine shifts in student-assessed identity development. Identity responses were also compared with averaged responses from each factor indicated by the EFA results to elicit any correlations between the factors and the science identity item.

Comparing Preprogram and Postprogram Responses. We assessed changes throughout the program by comparing scores on the presurveys and postsurveys using Welch two-sample t tests for each of the four latent factors identified by the EFA and Mann–Whitney U test for the identity item. To protect participant confidentiality, identifying information was not collected with the surveys. Thus, individuals' responses cannot be paired, preventing us from using paired t tests, which would be appropriate given the nonindependent samples. Thus, our data violate the assumption of independence of the t test and our risk of type 1 error is inflated. We mitigate this limitation by adopting a conservative critical value for interpreting the significance of the tests. We use a Bonferroni correction for the five comparisons made in this study and accordingly adopt a critical value of 0.01.

REMS Participant Co-author Reflections. Parts of this discussion offer an additional lens of reflection from an alumna of the program who is now a researcher and included here as a co-author (S.C.G.). Being part of this program first as a student participant, then a near-peer student mentor, an undergraduate intern, and presently, a graduate assistant of the program that helps in the development and delivery of course content for this program, this author provides a unique perspective to the analysis. Another context that frames S.C.G.'s analysis is the experience in marine science courses offered in a continental United States university serving a heavily Caucasian population, as well as experiencing the evolution of this Hawai'i place-based immersive REMS program. Although one voice cannot represent the entire sample population of the survey used in this analysis, having a brief insight into the interpretation of this data based on personal, lived experiences offers an additional lens of data interpretation.

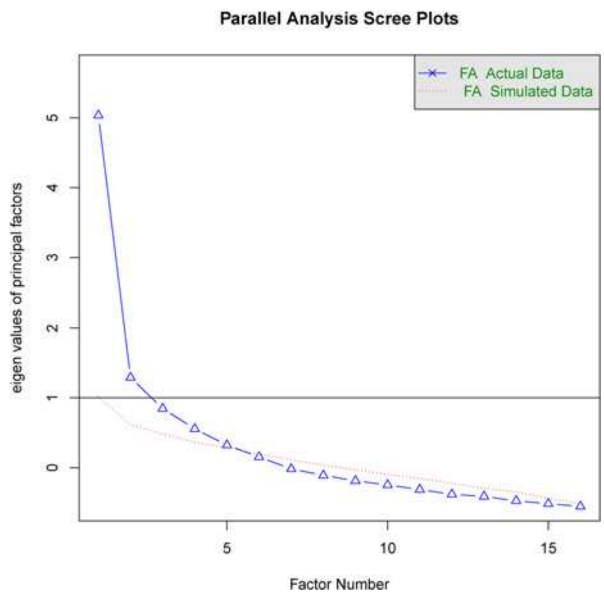

FIGURE 2. Visual scree plot parallel analysis indicating that five factors have an eigenvalue greater than that of the simulated dataset.

RESULTS

We found that our data did not severely violate assumptions of normality: all items had skewness <2.0 and kurtosis <7.0. Next, initial exploratory analyses showed evidence for latent factors within the dataset. Bartlett's test of sphericity indicated the observed correlation matrix for both the preintervention and postintervention datasets were significantly different ($p < 0.001$) from the identity matrix (Bartlett, 1950; Dziuban and Shirkey, 1974). This was encouraging given that the identity matrix (rejected, here) is a case where there is a complete lack of relationships between items in the dataset (Howard, 2016). In addition, the KMO measure of sampling adequacy was greater than 0.6 for all items (Supplemental Table S1) indicating that a common variance structure (and thus, latent factors) is present in the data (Kaiser, 1970; Dziuban and Shirkey, 1974). In contrast to the binary (significant vs. nonsignificant) result from Bartlett's test of sphericity, the KMO measure of sampling adequacy provides a continuum of common variance within the dataset. The preintervention dataset ranged between 0.68 and 0.89 ("okay" to "good"), while the postintervention dataset ranged between 0.83 and 0.94 ("good" to "great"; based on Howard 2016's categories of acceptable variance). Lastly, histograms of each item indicate shifting distributions (e.g., increasing means) between the preintrevention (Supplemental Figure S1) and postintervention (Supplemental Figure S2) datasets. This suggests a potential effect of the intervention on student self-assessment. Overall, these initial exploratory analyses yielded promising results that validate our decision to further investigate the dataset through EFA.

Parallel analysis (Figure 2) indicated that five factors have an eigenvalue greater than that of the simulated dataset. This can be thought of as a theoretical ceiling for the number of factors to retain. Therefore, we estimated EFA models with 2, 3, 4, and 5 factors.

TABLE 2. Results of EFA displaying loadings of each item onto four latent factors. Loadings >0.5 (the cutoff value that was used to determine associations between items and latent factors) are bolded. All other loadings and items not associated with any latent factor are shown in italics

Abbreviated item	Scientific Skills	Interest	Integration	Content Understanding
Career	*− 0.0293*	*1.0625*	*− 0.3794*	*0.2407*
Confident research	*0.2628*	*0.1138*	*0.3072*	*0.2570*
Confident understanding	*− 0.1380*	*0.4966*	*0.2590*	*0.4251*
Discussing	*0.0272*	**0.7593**	*0.1147*	*− 0.1837*
Enthusiastic	*0.0035*	**0.7193**	*0.0535*	*− 0.1132*
Willing with others	*0.1316*	*0.1790*	*0.3562*	*− 0.2059*
Applying knowledge	*0.0186*	*− 0.0847*	**0.8591**	*0.0071*
Connecting knowledge	*− 0.0699*	*− 0.1440*	**0.9362**	*0.1981*
Develop H0	**0.8834**	*− 0.0002*	*− 0.0952*	*0.0304*
Test H0	**0.8594**	*− 0.0376*	*0.0497*	*− 0.0920*
Evaluate H0	**0.8674**	*0.0038*	*− 0.0282*	*0.0725*
Effective with others	*0.3554*	*0.0878*	*0.0373*	*− 0.1075*
Ecology	*− 0.1212*	*− 0.0545*	*0.2739*	**0.6889**
Fertilization	*0.1966*	*0.0243*	*− 0.1661*	**0.7022**
Relate to life	*0.3125*	*− 0.0088*	*0.1514*	*0.0568*
Scientific process	*0.4762*	*− 0.0867*	*− 0.0774*	*0.2207*

We examined each EFA model to examine the coherency and interpretability of each solution. We determined that the four-factor model was most appropriate, relying heavily on the lived expertise of the alumna co-author. Models with fewer latent factors were difficult to interpret as the content and meaning of each factor was less clear. For example, when using three latent factors, items related to hypothesis testing and formulation (i.e., Develop H0, Test H0, and Evaluate H0) loaded onto the same factor as items themed on integration (i.e., Relate to Life). The five-factor model included three latent factors estimated by only two items and were not coherent and interpretable. The existence of four latent factors in the data is further supported by its consistency with previous research using the same dataset (Ambrosino and Rivera, 2022).

The pattern matrix for the four-factor EFA is shown in Table 2. Some items did not exhibit simple structure (i.e., loading strongly onto only a single factor). We adopted a pattern coefficient cutoff of 0.5, meaning that at least 50% of the variance in an item should be explained by the latent factor. There were six items (Confident research; Confident understanding; Willing with others; Effective with others; Relate to life and Scientific Process) that did not meet this cutoff and were dropped from the measurement model (Table 2). Note that relaxing the cut-off value to 0.4 only resulted in one additional item being retained in the final model. Thus, we proceeded with the high cut-off value of 0.5 so that only items with strong loadings are included in the final model. In addition, one item (Career) had a loading greater than 1.0, constituting a Heywood case. We excluded this item following best practices (Cooperman and Waller, 2022). Based on the content of the items loading onto each latent factor, we named the four latent factors (Table 3): Scientific Skills, Interest, Integration, and Content Understanding.

Welch two-sample *t* tests were used to compare pre versus post mean values for each of the four latent factors. We find the mean values increased in all cases (Table 4, $p < 0.001$). Specifically, students' self-assessed abilities as they relate to the scientific skills, integration of knowledge, specific content understanding, as well as their acknowledged interest in marine science all increased after the intervention.

Results from the science identity item on the 2023 REMS survey demonstrated a nonsignificant increase in the average agreement with the phrase "I am a scientist" by student participants after participation in the program (Figure 3; $U[N_{pre} = 21, N_{post} = 15] = 91.5, z = -2.10, p = 0.036$). There were no significant correlations between the learning gains factors and the identity item.

DISCUSSION

In order for institutions to work towards authentically delivering diversity and inclusion initiatives, such as the University of Hawai'i's goal of becoming a NHPoL, programs must be able to provide holistic training to students that prepare them for real-world experiences navigating science communities. The results from these analyses present evidence that culturally relevant, place-based research programs such as REMS are able to provide such rigorous and humanized experiences. Professional research and science-related careers (e.g., resource management, environmental policy, STEM education) require a broad spectrum of skills and knowledge that include conceptual understanding, problem solving, critical thinking, communication, and social skills.

This study assessed latent factors of learning gains and development of reported science identity in student participants of REMS, a place-based, summer research program developed to support research training for Hawai'i students transitioning into undergraduate pathways. We assessed how eight cohorts of participants in the REMS program benefited from the experience. We found that students experienced increases in their self-assessed Scientific Skills (self-assessed confidence in ability to apply the scientific process and hypothesis testing), Content Understanding (self-assessed understanding of specific topic areas taught during REMS), Interest (acknowledged interest in and enthusiasm for marine science), and

TABLE 3. Descriptions and items associated with each of the four latent factors

Latent factor	Description	Items
Scientific Skills	Student's self-assessed understanding of the scientific process and hypothesis testing.	Presently, I can use the scientific process to ask a question and develop a hypothesis Presently, I can analyze and interpret experimental data to evaluate a hypothesis Presently, I can develop an experiment to test a hypothesis
Interest	Student's self-assessed interest in and enthusiasm for marine science.	Presently, I am interested in discussing marine science with friends or family Presently, I am enthusiastic about marine science
Integration	Student's self-assessed ability to integrate and extend ideas from the classroom to other areas of life.	Presently, I am in the habit of applying what I learn in classes to other situations Presently, I am in the habit of connecting key ideas I learn in my classes with other knowledge
Content Understanding	Student's self-assessed understanding of specific topic areas taught during the summer program.	Presently, I understand the ecology of coral reefs. Presently, I understand the effects of water quality on the fertilization processes of marine organisms, particularly sea urchins.

Integration (self-assessed ability to integrate and extend ideas from the classroom to other areas of life).

Latent Factors of Learning Gains

Scientific Skills and Content Understanding loaded as distinct competency factors in our analysis of student responses. Scientific Skills encompass the processes and methodologies individuals use to engage with scientific information and solve problems, while Content Understanding involves the knowledge of the specific information and concepts within a scientific discipline. Analyses from studies examining these factors in national surveys that aggregate data from predominantly White student populations, or surveys that examine factors within other scientific disciplines (e.g., Chemistry, Physics, Computer Science) suggest Scientific Skills and Content Understanding can be represented as a single factor (e.g., Garcia *et al.*, 2018). Although our data suggest that these competencies are separate factors that contribute to learning gains, this may be due to either the composition of our student population or the field in which we work (marine sciences). A recent study examining science identity in prehealth students at community colleges suggests similar factor loading nuances of SALG survey data for prenursing and preallied health students from marginalized ethnicities (Perkins *et al.*, 2023). In parsing out a student's confidence in being able to perform science (i.e., skills) and confidence in competency (i.e., understanding), the results of the current analysis echo similar distinctions in factors related to student science identity constructs reported by Carlone and Johnson (2007) in their seminal identity framework paper—a paper in which the participants were women of color.

Although students reported gains in all the latent factors, the largest postprogram gains were reported in the Content Understanding factor, followed by the Scientific Skills factor. It is encouraging that students reported the greatest gains in Content Understanding while participating in a largely experiential-based, textbook-optional program. In considering this result, S.G.C. reflected on her experience as a product of the Hawai'i public school system. Although the local universities are home to world-renowned marine biology and oceanography programs and research institutes, and the campuses are situated on a tropical island chain, many public school curricula in the state of Hawai'i do not build marine science content into their coursework. Although some public high schools in Hawai'i are setting examples of how to successfully deliver project-based marine science curricula, marine science classes are often designed as a lecture-based elective that typically does not offer immersive experiences or content grounded in contemporary climate issues such as those covered during REMS (e.g., ocean acidification and its impacts on fertilization rates for native marine organisms). S.G.C. noted that she and her peers experience the ocean and

TABLE 4. Mean values for four latent factors calculated based on student self-assessment responses in the preintervention versus postintervention questionnaires. All differences between pre and post were statistically significant ($p < 0.001$). Responses on a scale of 1 = not at all to 5 = a great deal. CI = Confidence Interval

Latent construct	Preprogram mean (95% CI)	Postprogram mean (95% CI)	Change (post-pre)	t-statistic	*p*-value
Scientific Skills	3.59 (3.48–3.70)	4.55 (4.47–4.63)	0.96	−14.1	$p < 0.001$
Interest	4.00 (3.87–4.14)	4.51 (4.40–4.62)	0.51	−5.72	$p < 0.001$
Integration	3.64 (3.52–3.76)	4.33 (4.23–4.43)	0.69	−8.64	$p < 0.001$
Content Understanding	2.47 (2.30–2.63)	4.42 (4.33–4.52)	1.95	−19.8	$p < 0.001$

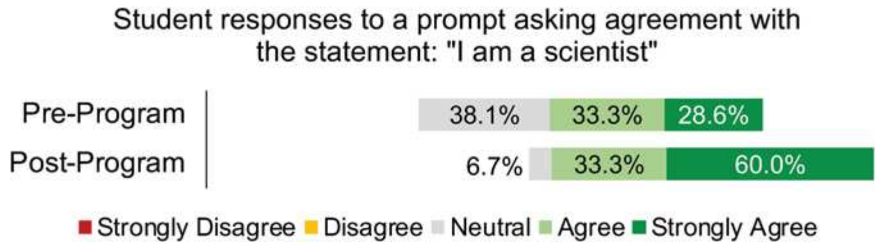

FIGURE 3. Student responses before and after participation in the REMS program to a REMS instrument prompt asking agreement with the statement: "I am a scientist." Responses on a 5-point scale (1 = Strongly Disagree; 5 = Strongly Agree).

shoreline habitats frequently outside of their academic schedules, and being exposed to inquiry-driven, hands-on marine science research experiences that incorporate native marine organisms or exploring local marine conservation issues can be transformational in how students relate to science. Increasing access for students to participate in such immersive research experiences that are not typically offered in their school setting increases opportunities to apply this knowledge and practice science skills in a real-world context. Thus, by introducing marine science concepts (in a Hawaiʻi-centric framework) and applying scientific skills alongside professional researchers, the program uses concepts and knowledge that are place-based and relevant to our students and can increase their confidence and scientific identity outside of the classroom.

Another latent factor emerging from our data was Integration, drawing upon acquired knowledge and applying it to different contexts. This might be particularly important when working with students from populations historically marginalized in STEM. How well students integrate information they learn across concepts or disciplines is often measured in assessments of learning gains as it may indicate whether students are developing a deeper and more meaningful understanding of subject matter. Thus, items assessing whether REMS students integrated ideas they learned from class with other courses or other knowledge were initially included in the first iterations of the REMS survey to evaluate the depth of student learning. However, as we reflect on the context in which REMS is delivered, the phrase "other knowledge" used in these items may have deeper implications for our students. In STEM education spaces in Hawaiʻi, and other areas with Indigenous people that were and/or are colonized by Western settlers, "other knowledge" may connote Indigenous knowledge or ways of knowing.

The REMS curriculum explicitly discusses the contributions of Western and Indigenous research and knowledge frameworks to the science community. The social and cultural context in which REMS takes place (e.g., research station in Hawaiʻi with students from Hawaiʻi) suggests another interpretation for the potential role an Integration factor may play in student learning: the students may be conceptualizing integration as reflective of how the REMS program experience integrates with other aspects of their lived experiences. Integration of knowledge with other aspects of social and personal identity may drive positive science identity development and resilience in navigating STEM pathways (Allaire, 2018; Ambrosino and Rivera, 2023). In her first year in an undergraduate program in a continental U.S. university, S.G.C. became acutely aware of the absence of personal connections to the content being delivered in a typical lecture-style introductory science course. She noted the Western context made it challenging to engage with or conceptualize new scientific concepts outside of the classroom, leaving that discouraging "why do these studies matter" feeling prominent with pursuing a degree in a STEM field. Understanding this lens is important for our students as many come from backgrounds in which the support of and connection to local community members is critical in fostering persistence in STEM, and thus should be more closely examined in future studies.

Learning Gains and Reported Science Identity

Responses to a science identity item included in the 2023 iteration of the REMS surveys showed a nonsignificant trend towards increasing reported science identity by participants in REMS, but these responses were not correlated with the latent factors of learning gains. This result may be due to the small sample size of survey responses from the 2023 cohort participants. It might also suggest that while a single-item measurement of science identity can be useful in certain contexts (e.g., McDonald *et al.*, 2019), data triangulation from additional measures should be considered for populations whose conceptualizations of science might differ from Western constructs.

A potential limitation to academic administrations fully embracing "humanized" training experiences might be that research training programs that purposefully incorporate the social or cultural side of science and time spent with "nonacademic" experiences (e.g., service days at community work sites) might detract from time spent in more traditional Western training practices (e.g., lectures on content, time in the lab). At the same time, preparing future professionals for the challenges of global climate change and biodiversity loss is not merely an academic or scientific problem. For example, governance and management of the Papahānaumokuākea Marine National Monument has largely been characterized as a success due to the commitment of diverse government agencies and nongovernment organizations, and individuals within each of these, to work towards shared understanding and mutual trust through effective communication and conflict resolution (Acton *et al.*, 2021; Chaplin-Kramer *et al.*, 2023). Students in the REMS program (which incorporates time spent developing social and cultural competencies) demonstrate significant increases in both their content understanding and scientific skills competency beliefs. Interestingly, the gains in these competency beliefs were greater than the other factors highlighted by the EFA. This demonstrates how a research training program enriched with meaningful, "humanized" experiences can provide students (particularly those with marginalized backgrounds) with the confidence and ability to reach academic benchmarks, even in natural science fields. As additional evidence to the efficacy of these types of programs, we have previously reported that REMS student content test scores significantly increased and were maintained in both immediate and longer-term time scales (Ambrosino and Rivera, 2022).

Limitations and Future Directions

Moving forward, we hope to continue collecting data from our students in order to provide training experiences that complement both the lived experiences of our students and the ever-changing needs of a technical and skilled workforce. With larger sample sizes, additional instrument items may load more strongly onto one of the latent factors suggested by the initial EFA, and thus expand our understanding of how students interpret and express confidence in science learning gains. A larger dataset would also allow us to begin comparing subgroups of participants to examine impacts from demographic factors, such as age, gender, ethnicity, etc. to better understand the context in which our students are responding to the surveys.

As we continue to undergo our own training as education researchers and better learn how to deliver and interpret assessment instruments, we will continue to develop the REMS survey through either rewording question items or editing the number of items. For example, we would like to add questions that are more targeted toward the latent factors highlighted by the EFA. Three of the four factors identified by the EFA only have two items, while ideally latent factors have at least three items to ensure model identification. Thus, a goal is to draft additional items for these latent factors. As an alumna of the program and a current instructor, S.G.C. noted that during REMS, students may not realize how they are growing across different dimensions of learning as suggested by the latent factors. She posited that the intentional delivery of the program and culturally responsive curriculum nurtures well-rounded growth in becoming a person of science. Reflecting now as an instructor who assists in the delivery of the course, she can see how this place-based immersive program enhances the inclusivity of ocean STEM education. Other conceptual factors that could be explored to understand the impact of this program could be specifically related to sociocultural issues that explore students' sense of belonging, identity crisis, and imposter syndrome that many of our students, including S.G.C., experience and express during this transitional bridge from high school to college (e.g., I belong in the field of science, I can make a difference in my community).

The wording of the REMS survey questions, in an effort to "fit" within the original Student Assessment of Learning Gains (SALG; Seymour *et al.*, 2000) instrument domains, may also be biasing student responses with leading questions. This might explain why the item, "Presently, I am interested in discussing marine science with friends or family" loaded onto the Interest factor. When examining the survey responses through an identity lens (Ambrosino and Rivera, 2022), we interpreted this item as fitting with items more closely related to an Integration (or Recognition) factor (specifically as discussing science topics with socially important figures could build a sense of a student's and others' sense of a student being a "person of science"). When S.G.C. reviewed the description of each latent factor, she initially classified this statement as also more closely related to the Integration (or Recognition) factor since concepts learned within the classroom are actively being applied to other areas of my life through conversations with friends and family rather than just being interested and enthusiastic in participating in these conversations. For future surveys, we could take this statement from an assessment of interest to an assessment of action or practice by posing the statement as "Presently, I discuss marine science concepts with friends or family." This may adjust students' self-assessed reflection that they do take concepts they learn inside the classroom to other areas of life such as talking about marine science with their friends and family.

The results from this study will continue to inform internal program development as we seek to support our students and the communities in which they live. Alongside program evaluation, we are also laying the groundwork for a formalized research coordination network that is envisioned to coordinate opportunities for students to further engage in authentic research experiences while promoting holistic learning through environmental and culturally grounded community service days and site exchanges across network partner sites. As the ultimate goal of this network is to strengthen and support undergraduate pathways in STEM, the network will build plans to create a sustainable framework to facilitate increased access to, engagement in, and recruitment into the network and education programs, and host interdisciplinary and cross-institutional events. We hope this network will provide a stable and supportive community in which students and professional researchers can benefit.

It is important to note that our study lacks a control group due to the nature of the program. In the future, as the program has grown to the point of having a waiting list, we could use a group of students interested in the program but unable to participate as a control.

CONCLUSION

Demonstrating the validity of measures for use with students from Native Hawaiian and Pacific Islander populations is crucial to address ethical and cultural considerations that arise when conducting research and developing curricula for and with Indigenous communities. Although important for supporting persistence of Native Hawaiian students in early-college science pathways in Hawai‘i, this insight has national significance as more Native Hawaiians now reside outside of (Hawaiian lands). The current analysis contributes to our understanding of how early college research experiences can support developing scientists from a diversity of backgrounds. It also highlights the importance of examining student experiences from multiple analytical angles, particularly when working with and for populations whose epistemologies and lived experiences differ from Western scientific contexts. Quantitative analyses, such as an EFA, and qualitative personal knowledge from instructors and the students themselves are both valid approaches that highlight different nuances in student experiences.

ACCESSING MATERIALS

All programming code used for this analysis can be found at https://github.com/kdgorospe/REMS-SALG

ACKNOWLEDGMENTS

We are grateful for the many significant contributions of people and programs throughout the years that have made REMS a success. Funders have included the Hauʻoli Mau Loa Foundation, Harold K.L. Castle Foundation, Pacific American Foundation, Carol Ann and Myron Hayashida, Omidyar ʻOhana Fund, Tanaka Memorial Foundation, National Science Foundation via PREL, Smithsonian Institution Youth Access Grant, SEED, METS, GPA and PLACES Programs at UHM, NOAA BWET, Heʻeia NERR, and other private donations. We would also like to acknowledge the support of the CC BIO INSITES network, funded through NSF.

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