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International Journal of STEM Education (2022) 9:70
https://doi.org/10.1186/s40594-022-00386-4

International Journal of STEM Education

RESEARCH

Open Access

A longitudinal analysis of developing marine science identity in a place-based, undergraduate research experience

Christine M. Ambrosino* and Malia Ana J. Rivera

Abstract

Background: Students from historically excluded groups face many pedagogical, societal, and institutional barriers that lead to disproportionately lower levels of entering and higher levels of attrition from Science, Technology, Engineering, and Math (STEM) undergraduate programs. Student experiences within a STEM learning environment play a large role in influencing participation and persistence in science, and place-based education (PBE) is one pedagogical approach that aims to increase student engagement with science. By allowing students to engage with scientific concepts through their own knowledge systems, PBE can develop these students' science identity and nurture a sense of belonging within the science community. This study examined student science identity in participants of a place-based, early-credit, Hawaiʻi undergraduate research experience, the Research Experiences in Marine Science (REMS) Program.

Results: Student science identity was measured via responses from pre- and post-program Likert-type surveys before and after participation in the REMS program along the dimensions of Performance/Competence, Interest, and Recognition. The science identities of REMS alumni who returned to participate in the program as near-peer mentors and undergraduate researchers were also measured to explore whether repeated exposure to the program experience continued to promote shifts in identity construct metrics. Results indicate that all student groups who participated in REMS, including alumni, gained confidence in their science content understanding and research skills, increased their interest in science as a subject and as a career pathway, and recognized how science affects their communities. New students demonstrated the largest shifts in their science identity metrics, but alumni also indicated further development of their science identities.

Conclusions: The data from this study suggest that the timing of interventions which aim to influence student science identity and persistence in STEM pathways is an important factor when targeting student groups transitioning to undergraduate programs. Future educational efforts to increase the positive development of student science identity should consider the potential benefits of cumulative research experiences to support students through their early careers as undergraduates in STEM.

Keywords: Science identity, Hawaiʻi, Marine science, Place-based, Undergraduate STEM experience

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Introduction

There is a well-documented interest to develop programs and pedagogies focused on increasing representation of demographics historically marginalized within the scientific community (Ballen et al., 2017; Estrada et al., 2016; Fisher et al., 2019; National Research Council 2012, 2012; Pierszalowski & Bouwma-Gearhart, 2018) due to the continued exclusion of certain minority populations entering Science, Technology, Engineering, and Math (STEM) undergraduate programs, and their higher rates of attrition from STEM academic and career pathways. The "leaky pipeline" of students from historically excluded groups (HEG) leaving STEM pathways may be attributed to both academic and non-academic barriers (Estrada et al., 2016; Pierszalowski & Bouwma-Gearhart, 2018). In Hawai‘i, Native Hawaiian and Pacific Islander students account for more than a quarter of the students in Hawai‘i Department of Education (HIDOE) schools, but they are underrepresented in undergraduate STEM programs (Kana‘iaupuni et al., 2021) and are taught by a faculty with even lower minority representation (*Mānoa's Racial and Ethnic Diversity Profile*, 2016).

One of the driving factors for the historical marginalization of certain student groups in STEM fields may be the incongruencies between their lived experiences and the culture of the science classroom or the science community. Research suggests students who already share cultural similarities with (or have a similar identity to) the stereotypical scientist are more likely to become a scientist than students who do not fit this narrative (Stets et al., 2017), while marginalized students (women and excluded minorities) face a disconnect between their personal, cultural identities and the identity of a "typical" scientist.

Place-based pedagogy in the science classroom

Place-based education (PBE) is one pedagogical approach that aims to increase student engagement with science content and thus increase student retention in STEM pathways through engagement with and nurturing of student identity. Student engagement has been described within the context of the science classroom as a multidimensional construct that comprises several sub-constructs including students' attitudes, interests, enjoyment, and self-beliefs, that taken together suggest an openness and eagerness to understand and use science (Woods-McConney et al., 2013). Science engagement is likely to be associated with particular background contexts or cultural factors which place-based curricula endeavor to acknowledge and integrate. Place-based science classes in Hawai‘i might include use of Hawaiian animal names or field trips to a local watershed (Kuwahara, 2013). In the instructional context of this study, modules incorporate the use of indigenous or endemic Hawaiian species, mo‘olelo (stories) and ‘ōlelo no‘eau (proverbial sayings), access to cultural practitioners and resource managers, and experiential field work in tropical coral reef ecosystems. By allowing students to engage with scientific concepts through their own knowledge systems, place-based education can simultaneously develop students' scientific and cultural identities (Kuwahara, 2013; van Eijck & Roth, 2009) which can nurture a sense of belonging in the science community.

Student science identity

A well-developed science identity may be a fundamental mechanism for increasing student persistence in STEM, especially among historically excluded student groups (Byars-Winston et al., 2016; Chang et al., 2011; Estrada et al., 2011; Flowers & Banda, 2016; Graham et al., 2013; Simpson & Bouhafa, 2020). Using identity as an analytic lens in science education research is a holistic and reflexive way to examine student experiences (i.e., by acknowledging specific contextual constructs of the classroom and the students) and may inform new views regarding teaching and learning in STEM (particularly in classrooms within the United States) (Gee, 2000). An examination of identity encourages educators and educational researchers to think about (a) the kinds of people targeted by science education (Are some students promoted while others are marginalized?); (b) the processes of learning and socialization in science (How do students affiliate with science? Is there a disconnect between a student's cultural and science identities?); and (c) the goals of science education (What defines a scientist?) (Carlone & Johnson, 2007).

For student science identity models, Gee's (2000) theory of identity often serves as a foundational framework, wherein "identity" is defined in broad terms as "[b]eing recognized as a certain 'kind of person', in a given context" (2000, p. 99). Science identity may be conceptualized as a type of "Role Identity" (i.e., identity within a given context, such as the science classroom) that interacts with a student's personal and social identities. Science education scholars have since begun to flesh out this initial construct, such as the science identity model proposed by Carlone and Johnson (2007) that incorporates three components: "Recognition", "Competence", and "Performance". The construct of Recognition includes seeing oneself as a scientist, and others seeing oneself as a scientist; Competence refers to self-assessed understanding of scientific content and utilizing scientific skills; and Performance describes the ability to socially conduct science practices within the science and general communities. There is also a growing trend of developing identity models specific to individual scientific disciplines, for example a student physics identity (Hazari et al., 2010), a computer science identity (Garcia et al., 2018), and a chemistry identity model (Hosbein & Barbera, 2020).

The model of science identity (Fig. 1) which guided the analyses in this study was based on models proposed by Carlone and Johnson (2007) and later refined by Hazari et al. (2010). This model focused on three dimensions

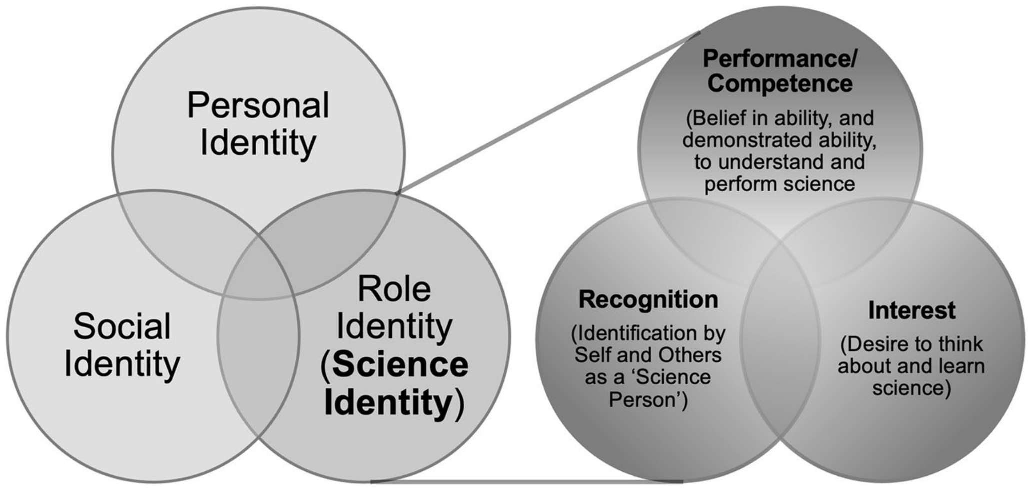

Fig. 1 Student Science Identity Model. Adapted from models originally developed by Carlone and Johnson (2007) and modified by Hazari et al. (2010)

of science identity: Recognition, Performance/Competence, and Interest. The first two dimensions, Recognition and Performance/Competence, were similar to the original factors described by Carlone and Johnson (2007), except that Performance and Competence were combined. Studies examining the contribution of each of these dimensions have shown significant overlap between performance and competence in developing a science identity (Garcia et al., 2018; Hazari et al., 2010; Potvin & Hazari, 2014), and so the analysis here utilized an integrated Performance/Competence construct. The final dimension of Interest was initially suggested by Hazari et al. (2010) as particularly fitting for examining identity in students, as a desire to participate or learn about science is considered especially influential to a student's science identity development and persistence in STEM fields. As this study also focused on students (late-high school, high school graduate, and early undergraduate students), this factor was especially relevant.

In another study which highlights the importance of science identity in predicting persistence in STEM, Vincent-Ruz and Schunn (2018) examined whether perceptions of personal and external views of one's identity as a person of science (i.e., recognition as a scientist, which they term "science identity") are independent from or integrated with other affective constructs such as (a) attitudes towards science (which includes fascination (i.e., interest)), (b) values (similar to the utility value of motivation theory), and (c) competency beliefs (i.e., competence in science). Their analysis incorporated (a) an exploratory factor analysis to examine whether recognition differed from the other affective constructs and (b) the use of multiple regression modeling to test whether science identity predicted student experience outcomes (predictive validity) and whether perceived internal and external identity predicts outcomes differently. The results of their analysis suggest perceived science identity and perceived recognition of science identity to be strongly tied together (i.e., self- and other (or external)-recognition are both important and linked). They also concluded that science identity overall is a strong predictor of students' science-related choices. Science identity behaves separately from other attitudinal factors regarding students' experience of science communities and has a unique contribution to our understanding of students' choices.

Current study

Building upon these models, this study sought to explore a framework for analyzing the constructs of science identity for Hawai'i students in a marine science classroom. The Research Experiences in Marine Science (REMS) Summer Program (Rivera et al., 2022), which provided the instructional context for this study, is integrated with place-based pedagogies that are grounded within a framework centered on content and practices relevant to tropical reef systems in Hawai'i. The courses were conducted at a marine research institute surrounded by a coral reef and delivered content based on contemporary marine science practices and projects conducted there. The concept of "place" in this study was heavily influenced by its physical location (isolated, Pacific, tropical reef), staff (predominantly marine scientists or oceanographers), and cultural context (Hawaiian methodologies with Native Hawaiian participants and mentors). However, beyond this specific context, REMS is an intensive introduction to general scientific methodology and training experience as a researcher that aims to provide students with a solid foundation in scientific principles and analytical methods that are suitable to any natural science field. Thus, for the purposes of this analysis, the constructs examined are considered indicative of general student science identity.

This study sought to address two (2) research questions regarding the development of student science identity in REMS. First, are the constructs of science identity shifted in Hawai‘i students after participating in a place-based, experiential research training program? Second, does recurrent exposure to place-based research communities and practices affect student science identity over time, especially during the high school–undergraduate transition? To examine these questions, this study analyzed data from content quizzes and program surveys to explore student science identity as aligned with the Performance/Competence, Interest, and Recognition constructs of identity.

Materials and methods

The study followed a pretest–posttest groups design to explore student perceptions and attitudes before and after participation in the study programs. To measure student science identity, the analysis follows an identity framework similar to that developed by Carlone and Johnson (2007) and elaborated by Hazari et al. (2010), as previously described.

Study location and course context

The data for this study were collected from 2013 to 2018 during the Research Experiences in Marine Science (REMS) Summer Program, and in 2019–2020 during the pilot of REMS Excel (REMS XL) at a Hawai‘i marine research station. REMS and REMS XL are 5-week (REMS) or 6-week (REMS XL) course-based undergraduate research experiences (CUREs) for Hawai‘i high school and early undergraduate students that emphasize tropical marine science (for detailed description of institutional and curricular context, see Rivera et al., 2022). During the REMS and REMS XL programs, the marine science content delivered in the modules is contextualized to reference the local biota and research community. The modules are all reflections of research conducted by professional scientists at the instructional research station. Students learn about different research methodologies and how they help address research questions and potentially increase understanding of local and global issues. The modules also include a mix of classroom- and field-based observations and experiments (sometimes the students bring the model organism into the classroom-laboratory, and sometimes the students must venture to the model organism's home environment).

As cultural and environmental integration is foundational to the Hawaiian sense of place (Oliveira, 2014), students are introduced to the history and significance of the program's place within the local ahupua‘a.[1] On the boat ride to the island, students listen to mo‘olelo of the ahupua‘a. Once seated in the classroom, students explore a map to locate the classroom building and describe how the small research station island was named. During the programs, students participated in field- and laboratory-based marine science modules (Ambrosino & Rivera, 2020; Fox et al., 2013; Gorospe et al., 2013; Haverkort-Yeh et al., 2013; Tamaru et al., 2014). Throughout the modules, animals are described with their Hawaiian names (e.g., mūhe‘e huna (Hawaiian bobtail squid, *Euprymna scolopes*)). Many of the animals and materials used in the laboratory classroom are collected by students from the reef and sand flats surrounding the classroom facilities. These elements, many already familiar to the students, emphasize the connection between the laboratory and the local research community. Just as importantly, instructors also demonstrate how these elements positively contribute to scientific methodologies.

Once oriented to the facilities and available resources, REMS and REMS XL students conducted independent research projects in small groups under the guidance of a team of transdisciplinary faculty who represented different disciplines (e.g., Biology, Neuroethology, Marine Science, Oceanography, ‘Ōlelo Hawai‘i, Evolution, Education), positions (e.g., teachers, professors, post-docs, grad students, undergrad interns), institutions (e.g., community college, research facility, traditional Hawaiian fish ponds, federal research reserve), and career levels (everything from undergraduate interns through tenured professors). REMS XL also included the addition of 13 professional development workshops. Six (6) workshops, which focused on statistical methods, were primarily delivered each week during the summer session. The other seven (7) workshops were delivered monthly (three (3) before the summer session, four (4) after the summer session) and covered topics relevant for early college pathways (e.g., professional online presence; time management; writing CV's and cover letters).

Participants

This study examined data collected from participants of the 2013–2018 REMS and 2019–2020 REMS XL summer programs. The target demographics for the REMS and REMS XL programs included students from Hawai‘i public schools (with an emphasis on Title I

[1] Hawaiian land division roughly analagous to a watershed system that stretches from mountain ridges to the adjacent coast and marine reef areas.

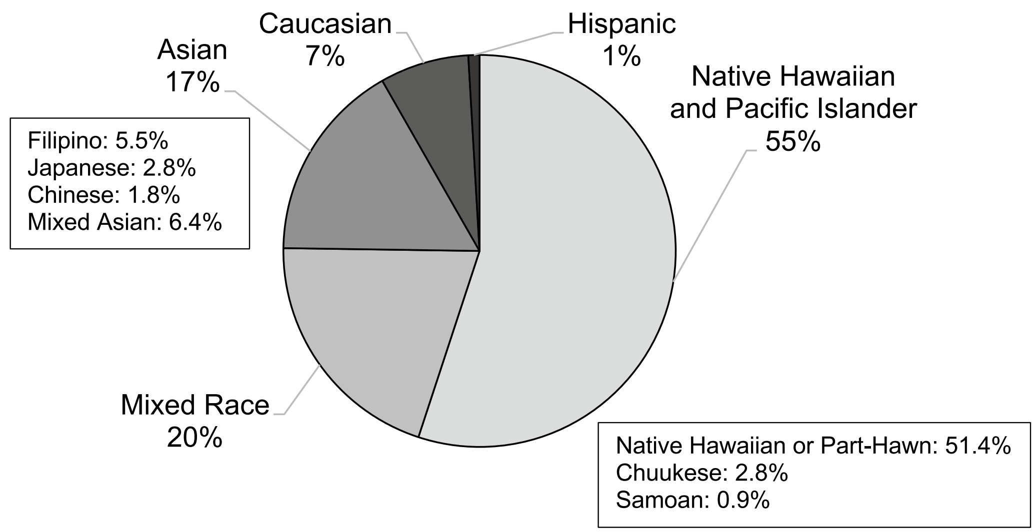

Fig. 2 Research Experiences in Marine Science (REMS) Program Participant Ethnicities. Self-reported ethnicities of total participants ($N=109$) in response to an open-ended question on program applications. Racial categories reflect those used by the University of Hawai'i (UH) System as per UH race and ethnicity reporting protocols: http://manoa.hawaii.edu/miro/wp-content/uploads/2014/07/Race-Ethnicity-Student-and-Faculty.pdf

complexes on O'ahu) from ethnicities historically marginalized in STEM fields. The authors were instructors for each year of the programs and developed the curricula. Anonymous survey data from each iteration of the REMS program were compiled alongside responses from 2018 REMS and 2019–2020 REMS XL students who were directly recruited into this study after University of Hawai'i at Mānoa Institutional Review Board approval (Protocol # 2019-00605).

Participants ranged in age from 15 to 24 years, and all were either attending or recent graduates of Hawai'i high schools or early undergraduate students. About 61% of the participants were female. The REMS and REMS XL programs target Native Hawaiian, Filipino, and Pacific Islander students, which made up a majority of participants (75% of students self-reported at least one of these ethnicities). A list of all self-reported student ethnicities is displayed in Fig. 2. All students participated in the REMS program at least once, while some REMS alumni returned to the program to participate as near-peer mentors for new students ($N=27$), or as participants in the REMS XL program ($N=12$) (Fig. 3). Unless otherwise noted, for each data set, first-time student (New Student group) data were analyzed separately from near-peer mentor (Mentor group) data, and REMS XL participant (REMS XL group) data to prevent pseudo-replication and confounding effects of participants who had previously experienced the course.

Instruments

The instruments for this study included assessments of student progress and programmatic evaluations produced through the REMS curriculum (i.e., iClicker content knowledge assessment and pre- and post-course program surveys). The program surveys were not included for either participatory points or calculation of student grades.

Content quizzes

Content knowledge was assessed with iClicker questionnaires during each module of the REMS program to monitor student retention of scientific concepts. The iClicker student response system included remotes that were assigned to each student with which they entered their answer choices, and a computer program that recorded student responses in a.csv file. As the content and question lists of the specific marine science modules delivered during the 2013–2018 iterations of REMS evolved from year to year, this analysis focused on New Student ($N=54$) and Mentor ($N=18$) responses for five (5) marine science modules that remained unchanged for three consecutive years: 2016, 2017, and 2018.

Each quiz consisted of eight (8) multiple-choice questions and was presented to the students three (3) times: (a) before the module lecture, (b) during the module lecture as content was covered, and (c) 1 week after the module. The first quiz helped the instructors gauge student knowledge before the experiential module, and students each answered individually. The students were

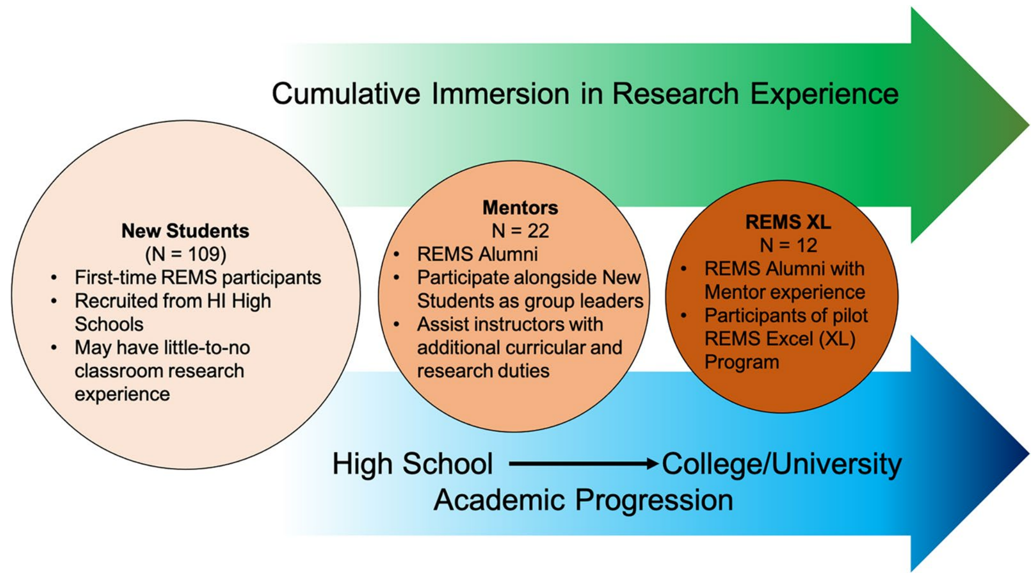

Fig. 3 Definitions of Program Student Groups. Mentors were recruited from the New Student group, and REMS XL students were recruited from the Mentor group

presented the questions a second time during the content lecture and were given approximately two (2) minutes to discuss the question with their peers before answering. Allowing student discussion through this modified informal cooperative learning method (similar to a think–pair–share format) has been associated with outcomes such as higher achievement, higher-level reasoning, and understanding of others' ways of thinking (National Research Council 2012, 2012). The third and final time the students saw the questions, one week later, they once again answered individually so the instructors could assess knowledge retention. Students were incentivized to perform well on these quizzes as the third score contributed up to 25% of the student's final grade for the program (along with participation, written reports, and an oral presentation which made up the remaining 75%). The average frequency of correct student responses was analyzed with two-tailed, paired Student's t-tests to determine differences between the pre- and post-module time points.

Research Experiences in Marine Science (REMS) program survey

Analyses of an anonymous survey consisting of five-point, Likert-scale questions and open-ended questions conducted via an online questionnaire on the first and last days of the courses were used to elucidate student content understanding, attitudes towards science and the scientific method, and thoughts about academic and career pathways. The SALG (Student Assessment of Learning Gains) survey platform is a free course-evaluation tool developed for college-level instructors to collect learning-focused feedback from their students (Seymour et al., 2000). Using this platform, surveys specific to the programs were developed. It should be noted that the survey instruments for this analysis were originally developed for general programmatic and pedagogic assessment, and not specifically to examine science identity constructs. However, SALG-based instruments provide a platform for students to evaluate personal growth and identity factors within a program that may influence that growth. Question items are grouped into categories that reflect aspects of science identity (e.g., questions that ask students to rate their understanding of marine science topics). The instruments also incorporate open-ended questions that encourage students to clarify and elaborate their numerical Likert-score responses. Thus, this platform which highlights student-driven assessment of learning experiences may provide insights to the development of idiosyncratic constructs such as science identity.

A total of 145 pre-program REMS surveys and 145 post-program REMS surveys were administered over the 2013–2019 REMS/REMS XL programs (New Student $N=106$; Mentor $N=27$; REMS XL Student $N=12$). Multiple choice items included a 5-point Likert-type scale (1 being the lowest or most negative response, and 5 being the highest or most positive response) with an additional response choice of "Not Applicable" (for a total of six (6) possible choices per item). Responses of "Not Applicable" were rare (accounting for less than 1% of responses for each item) and were excluded from the analyses.

In the most recent iterations of the REMS surveys, there were two versions of the survey for both the pre- and post-course iterations: (1) a version for New Students, and (2) a version for Mentors. The only difference between these versions was the addition of a "Mentor" question section for the Mentor students. For the REMS XL program, an analogous version of the REMS survey was administered that replaced the "Program Evaluation" section with a "Workshop Evaluation" section, and the "Group Project Evaluation" section with a "Professional Development" section. Earlier iterations of the REMS survey, which were also included for analysis, had the same basic structure (with "Mentor" questions first appearing in 2015) but slightly different numbers of questions, as the course content and survey focus has shifted slightly throughout the years (e.g., items asking about an animal behavior module instead of a larval development module, depending on the content included that year). In general, the pre-course survey consisted of 26 to 28 five (5)-point Likert-score questions and six (6) to 12 open-ended questions. The number of Likert-scale items differed slightly between the years as content was added or removed due to the syllabus schedule. The number of open-ended questions increased over the iterations as the instructors wished to gain more insight to student survey responses for programmatic development. An additional seven (7) Likert-score questions were included for the Mentor version of the instrument. The post-course survey included a repeat of the pre-course survey questions, plus an additional 11 Likert-score questions (to evaluate the REMS program content and experiences with group research projects) and five (5) open-ended questions (program evaluation questions and a question asking for advice for future students).

This study focused on a subset of the overall questions (17 Likert-score items) that aligned with the constructs of a place-based science experience and the identity model (i.e., Recognition, Performance/Competence, and Interest) (Fig. 4). Questions were primarily chosen with regard to their connection to the constructs of place and identity, as well as to minimize missing data and maximize consistency through the course iterations. The iClicker content quiz questions, which illustrated the demonstrated performance, combined with items related to self-assessed competence, such as questions that asked students to rate their content understanding (e.g., "Please rate your agreement with the following statement: *I understand* the ecology of coral reefs.") or ability to utilize a research skill (e.g., "*I can* develop an experiment to test a hypothesis."), easily fit within the Performance/Competence construct. Survey items that asked students to rate their attitudes towards or interest in specific program modules (e.g., "Please rate your interest on the Ocean Acidification laboratory module.") or interest in pursuing a science pathway (e.g., "I am interested in taking classes in or pursuing a career in marine science.") were categorized under the Interest construct. For the Recognition construct, survey items were chosen to elucidate relational dimensions between the students and the science community through confidence in their science self-efficacy (e.g., "I am confident that I understand marine science."), relevance of science (e.g., "Please rate your agreement with the following statement: I understand how ideas in this class relate to my own everyday life.") and whether scientific concepts and skills are integrated in other areas of their lives (e.g., "I am in the habit of connecting key ideas I learn in my classes with other knowledge."). We acknowledge that the constraints of using a convenience sample of survey items from a program evaluation instrument prevented the incorporation of direct questions reporting recognition as a person of science (e.g., "Please rate your agreement with the following statement: I am a scientist."). The items presented here are indirect and more nuanced as they ask students about the relevance and integration of science to their lives. However, for Indigenous student populations, developing meaningful connections to home community members, personal life experiences, and cultural epistemologies in science learning environments is especially critical for supporting persistence in the STEM community (Allaire, 2018; Bang & Medin, 2010; Berland et al., 2016; Page-Reeves et al., 2019).

In addition to being grounded within the analytical framework, the survey items were reviewed by science and education researchers (including scholars of science identity and Native Hawaiian/Pacific Islander student experiences) to confirm alignment with relevant constructs and content knowledge. The survey items delivered during the program asked students about their competence in science and marine science knowledge and skills, interest in science and marine science, and relevance of science and marine science to their lives. Pre- and post-course survey scores were analyzed with a two-tailed Student's t-test to highlight statistical changes in student responses.

Results

The results of the analyses were organized thematically along the three components of the science identity model. Before- and after-program REMS survey responses were collected from 109 participants as either first-time students, near-peer mentors, REMS XL participants, or a

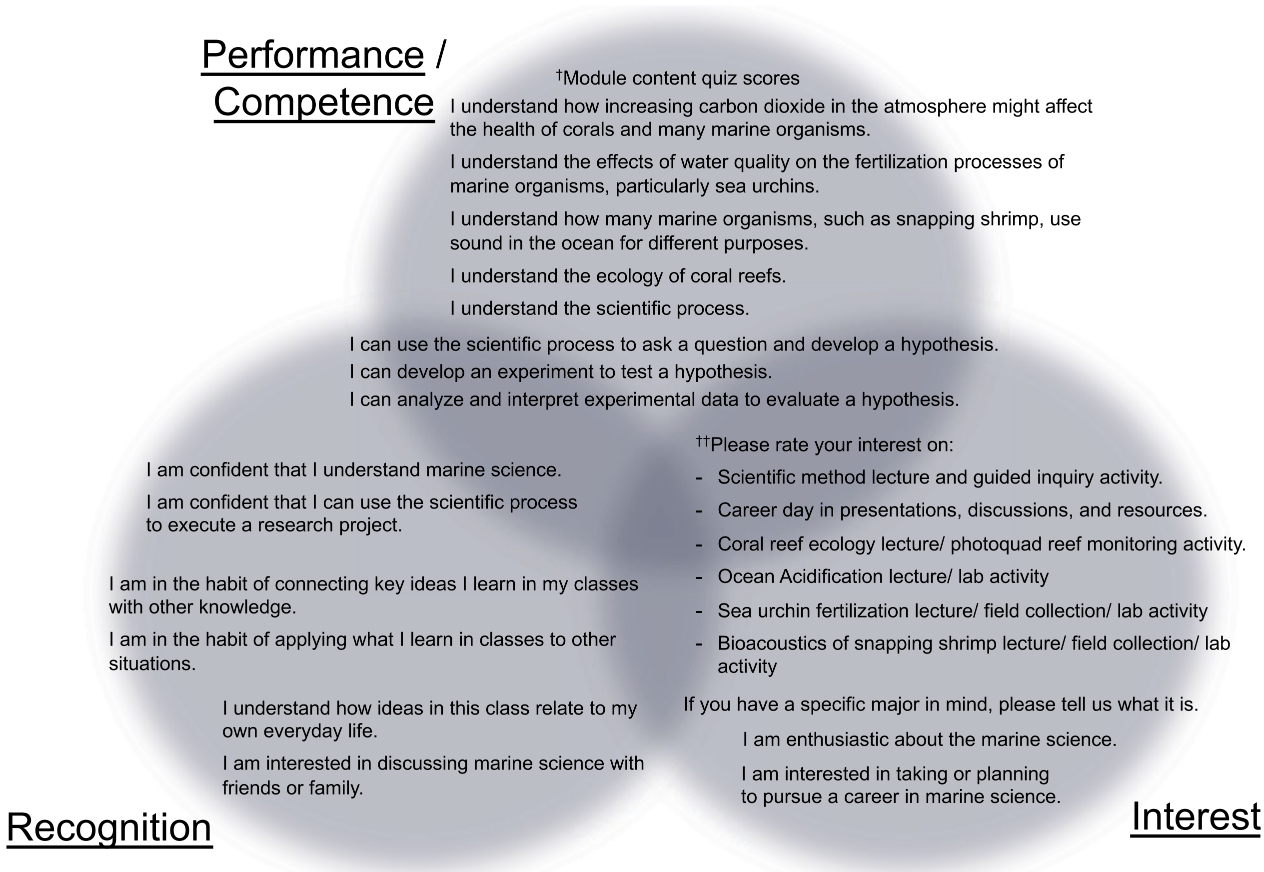

Fig. 4 Instrument Items within Identity Framework. *Note*. Categorization of iClicker module quizzes and Research Experiences in Marine Science (REMS) Program survey items aligned with the science identity model constructs they reflect. The overlapping background circles in the image reflect the overlapping nature of the identity constructs. The survey items are ordered and indented to fit within the construct circles and to indicate related questions from neighboring constructs. †Quiz scores are collected from iClicker multiple-choice quizzes delivered during the marine science modules. ††This group of "Interest" questions are part of the program evaluation portion of the survey instrument delivered on the final day of the program

combination of these designations. Thus, 282 surveys in total were completed between 2013 and 2020.

Performance/competence

iClicker quizzes

The Performance aspect of science identity was assessed by analyzing student responses to eight (8) multiple-choice questions in each of five (5) marine science modules via iClicker content quizzes. The topics for the modules included: ocean acidification, sea urchin fertilization, marine bioacoustics/behavior, coral reef ecology, and the scientific method. Figure 5 compares the pre–post average correct scores of New Students and Mentors. For New Students, the post-program average correct scores increased significantly for each module ($t(52)$, $p<0.001$). Mentors also showed significant improvements in each of their quiz assessment ($t(17)$, $p<0.05$), with the exception of the scientific method module for which there was no observable change in scores ($p=0.75$). A one-way ANOVA revealed that there was a significant difference across pre-module scores for both New Student ($F(4, 255)=24.53$, $p<0.001$) and Mentor ($F(4, 78)=13.2$, $p<0.001$) groups (Fig. 6). Tukey's HSD test for multiple comparisons found that both New Students and Mentors on average scored lowest on the Ocean Acidification module quiz before the program. In post scores, New Students still scored significantly lower on the Ocean Acidification module than any other module, but Mentor post scores were similar for all modules. Average quiz scores were also compared between the student groups to examine if Mentors performed differently than New Students (Fig. 7). In three of the modules (Sea Urchin Fertilization: $t(64)=3.85$, $p<0.001$; Marine Bioacoustics: $t(66)=3.01$, $p=0.003$; Scientific Method: $t(65)=2.96$, $p=0.004$), New Student pre-module scores were lower on average than Mentor pre-module scores,

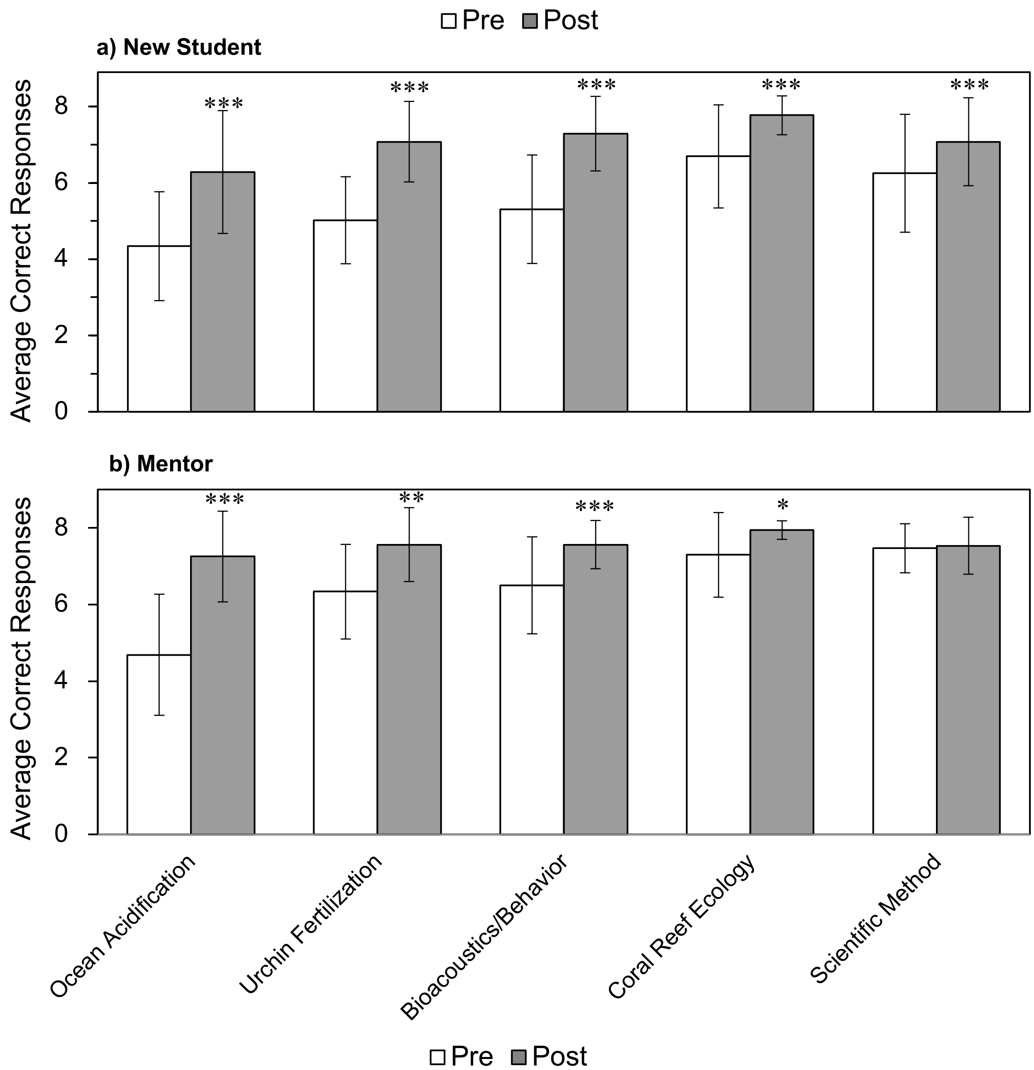

Fig. 5 Performance: Comparing pre- and post-module iClicker Quiz scores. Average items answered correctly on 8-question iClicker content quizzes, collected from **a** New Students ($N=54$) and **b)** Mentors ($N=18$) during the 2016–2018 REMS programs. Pre–post differences in score averages were compared with a paired Student's *t*-test. *$p<0.05$. **$p<0.01$. ***$p<0.001$

but there were no differences between post-module scores between student groups. For the Ocean Acidification module, Mentors and New Students scored similarly before the module, but after the module Mentors significantly out-scored New Students ($t(67)=2.22$, $p=0.03$). There were no pre- or post-module differences between student group scores for the Coral Reef Ecology module.

REMS program survey

Student science Competence was assessed with five (5) Likert-scale items (see Fig. 4). The survey items asked students to rate their understanding of content related directly to the content modules (i.e., Ocean Acidification, Sea Urchin Fertilization, Marine Bioacoustics, Coral Reef Ecology, Scientific Method). By the end of the program, New Students reported an increased understanding of all topics (Ocean Acidification: $U(N_{pre}=50,\ N_{post}=53)=271$, $z=6.88$, $p<0.001$; Sea Urchin Fertilization: $U(N_{pre}=50,\ N_{post}=53)=526$, $z=5.27$, $p<0.001$; Marine Bioacoustics: $U(N_{pre}=50,\ N_{post}=53)=270.5$, $z=6.88$, $p<0.001$; Coral Reef Ecology: $U(N_{pre}=50,\ N_{post}=53)=330.5$, $z=6.56$, $p<0.001$; Scientific Process: $U(N_{pre}=50,\ N_{post}=53)=466$, $z=5.66$, $p<0.001$) (Fig. 8). Mentors reported an increased understanding for Ocean Acidification ($U(N_{pre}=17,\ N_{post}=15)=57.5$, $z=-2.62$, $p=0.009$), Sea Urchin Fertilization ($U(N_{pre}=17,\ N_{post}=15)=45$, $z=-3.1$, $p=0.002$), and Coral Reef Ecology

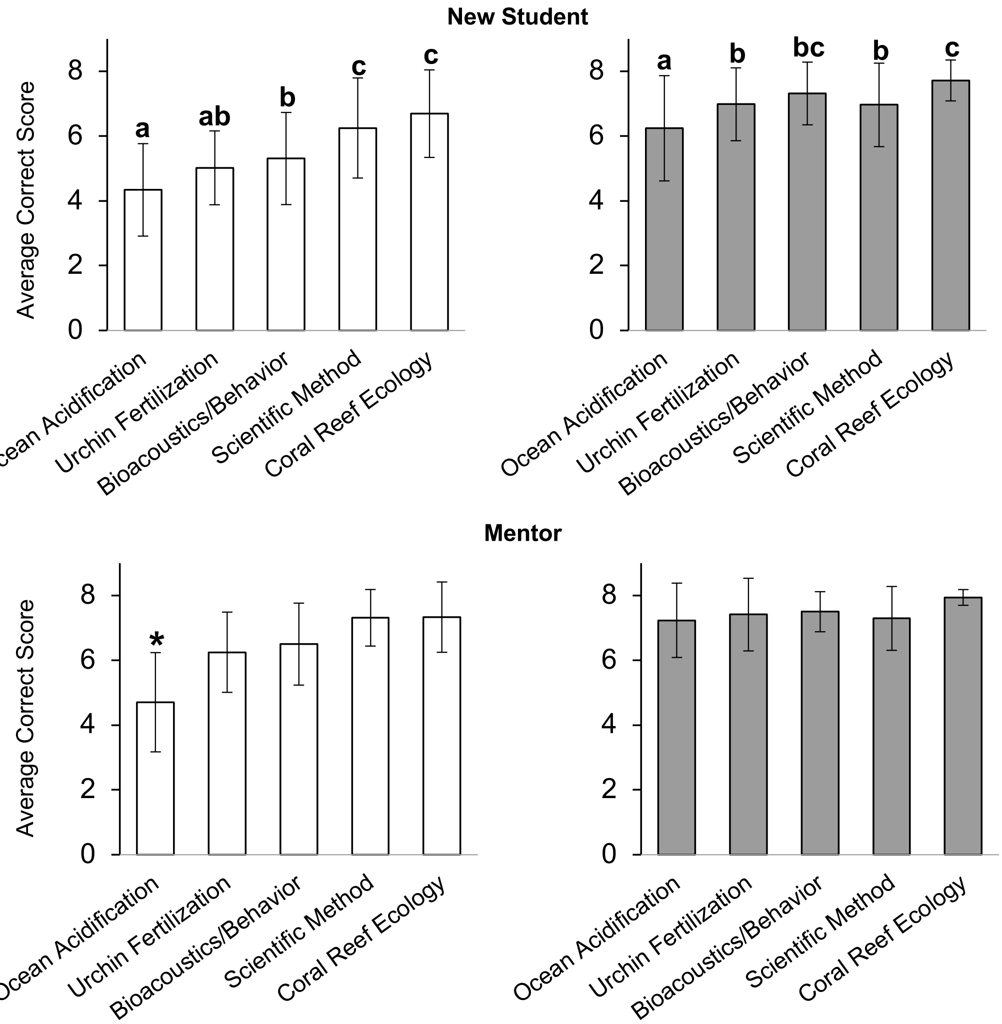

Fig. 6 Performance: Comparing iClicker Quiz scores among modules. Average correct responses on 8-question iClicker content quizzes, collected from (top) New Students (*N* = 54) and (bottom) Mentors (*N* = 18) during the 2016–2018 REMS programs. Differences between modules were compared with an ANOVA and post hoc Tukey tests. Letters not in common above New Student average score bars indicate significant differences between modules. For example, in the New Student pre-program data, Ocean Acidification scores (group "a") were significantly different from Bioacoustics/Behavior scores (group "b"). Ocean Acidification scores (group "a") were not significantly different from Urchin Fertilization scores (group "ab"). *$p < 0.05$

($U(N_{pre} = 17, N_{post} = 15) = 37.5, z = -3.38, p < 0.001$) (Fig. 9).

Comparing differences in competence scores between student groups (Fig. 10), New Students reported lower understanding than Mentors before each module (Ocean Acidification: $U(N_{New\ Student} = 50, N_{Mentor} = 17) = 158.5$, $z = -3.78$, $p < 0.001$; Sea Urchin Fertilization: $U(N_{New\ Student} = 50, N_{Mentor} = 17) = 269.5$, $z = -2.23$, $p = 0.03$; Marine Bioacoustics: $U(N_{New\ Student} = 50, N_{Mentor} = 17) = 123.5$, $z = -4.23$, $p < 0.001$; Coral Reef Ecology: $U(N_{New\ Student} = 50, N_{Mentor} = 17) = 210.5$, $z = -3.08$, $p = 0.002$). Scientific Process understanding scores were compared among New Student, Mentor, and REMS XL student groups. A Kruskal–Wallis test indicated a significant effect of student type on pre-module scores ($H(2) = 14.2$, $p < 0.001$). Post hoc Dunn's tests with Holm adjustment showed differences between the pre-module scores of New Students and Mentors ($p = 0.002$) and New Students and REMS XL students ($p = 0.02$).

To explore whether student-reported competence correlated with actual quiz score performance, average correct quiz scores were correlated with average competence scores per module within each student group (Fig. 11). New Student competence and performance scores were significantly positively correlated ($r(9) = 0.76$, $p = 0.01$)). Mentor competence and performance scores

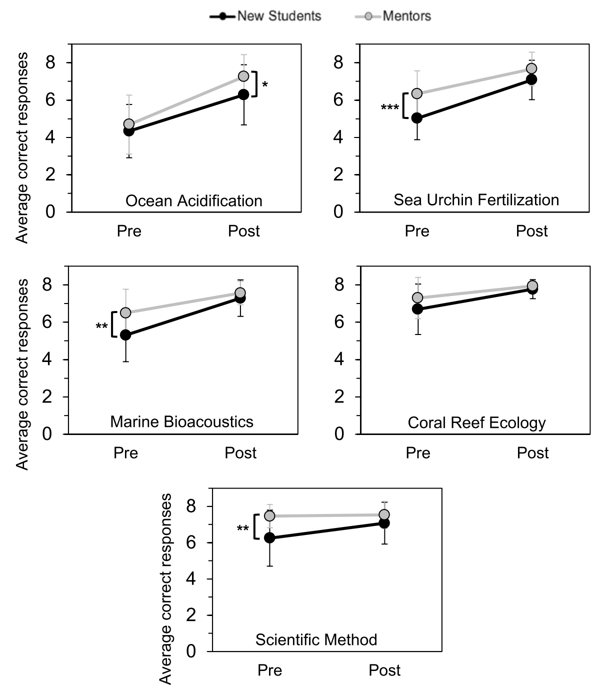

Fig. 7 Performance: Comparing iClicker scores between student groups. Differences between student groups compared with paired Student's *t*-tests. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$

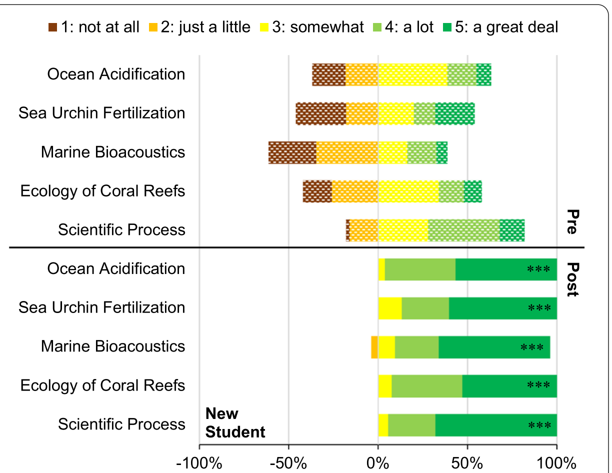

Fig. 8 Competence: Pre- and post-program new student science knowledge competence. Responses to competence REMS survey items of perceived understanding (1 = Not at all, 5 = A great deal) relating to five (5) program modules from New Students ($N = 54$) in the 2016–2018 REMS programs. Differences in pre–post scores were analyzed with Mann–Whitney *U*-tests. ***$p < 0.001$

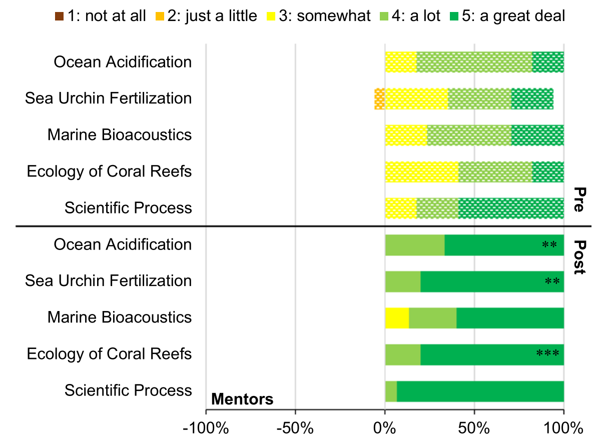

Fig. 9 Competence: Pre- and post-program mentor science knowledge competence. Responses to competence REMS survey items of perceived understanding (1 = Not at all, 5 = A great deal) relating to five (5) program modules from Mentors ($N = 18$) in the 2016–2018 REMS programs. Differences in pre–post scores were analyzed with Mann–Whitney *U*-tests. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$

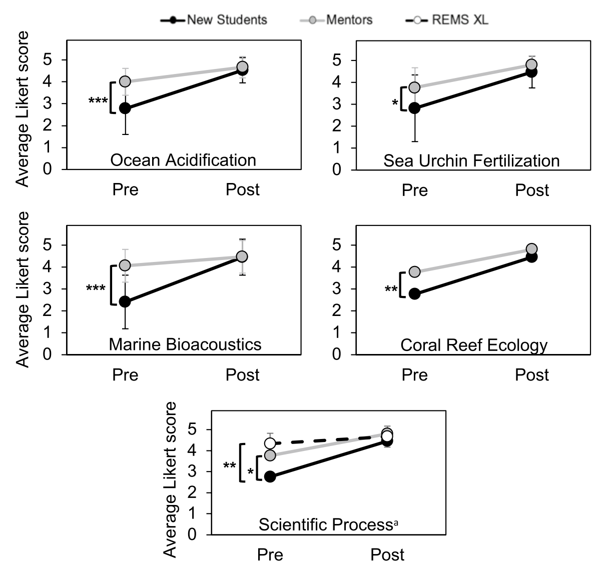

Fig. 10 Competence: Comparing science knowledge competence scores among student groups. Average Likert scores (1 = Not at all, 5 = A great deal) on REMS survey items collected from New Students ($N = 54$) and Mentors ($N = 18$) in the 2016–2018 REMS programs, and REMS XL students ($N = 12$). Differences among student groups compared with Mann–Whitney tests for two groups, and Kruskal–Wallis with post hoc Dunn's tests for three groups. [a]The survey for REMS XL students only included this item. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$

were moderately, although not significantly, correlated ($r(9) = 0.58$, $p > 0.05$).

The other REMS survey items relating to marine science competence asked students to rate their ability to execute scientific tasks ("I can use the scientific process to ask a question and develop a hypothesis."; "I can develop an experiment to test a hypothesis."; "I can analyze and

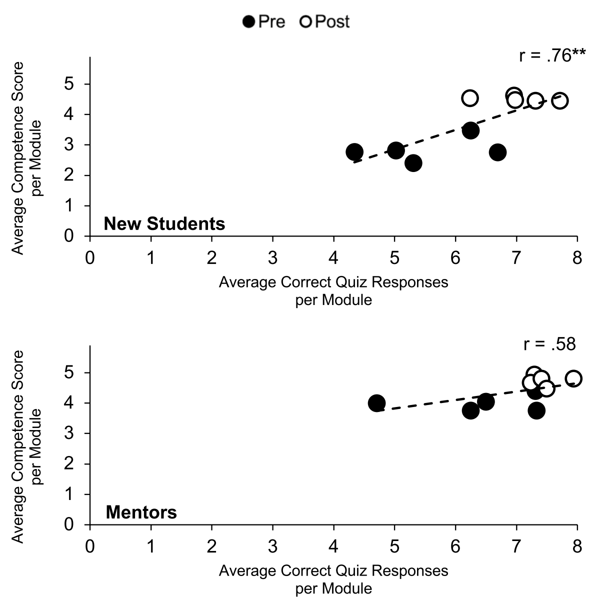

Fig. 11 Correlation of Student Performance (iClicker) and Competence (REMS Survey) Scores. Correlated performance and competence scores of new students (top, $N = 54$) and Mentors (bottom, $N = 12$) in the REMS 2016–2018 programs. Each dot represents the coordinate score (x = average correct quiz responses, y = average competence score) for a REMS module (e.g., ocean acidification, marine bioacoustics). Black dots are pre-program scores, and white dots are post-program scores. $^{**}p = 0.01$

interpret experimental data to evaluate a hypothesis."). Figure 12 illustrates response ranges from New Students, Mentors, and REMS XL students. New Students reported significant increases in perceived abilities for all three items (Analyze data: $U(N_{pre} = 103, N_{post} = 102) = 2434.5$, $z = -6.64$, $p < 0.001$; Develop experiment: $U(N_{pre} = 103, N_{post} = 102) = 2104.5$, $z = -7.41$, $p < 0.001$; Scientific method: $U(N_{pre} = 103, N_{post} = 102) = 2344$, $z = -6.84$, $p < 0.001$), while Mentors (Analyze data: $U(N_{pre} = 26, N_{post} = 27) = 229$, $z = 2.16$, $p = 0.03$; Scientific method: $U(N_{pre} = 26, N_{post} = 27) = 255$, $z = 2.23$, $p = 0.03$) and REMS XL students (Analyze Data: $U(N_{pre} = 12, N_{post} = 9) = 15$, $z = -2.74$, $p = 0.006$; Develop experiment: $U(N_{pre} = 12, N_{post} = 9) = 20.5$, $z = -2.35$, $p = 0.02$) reported significant gains for two of the three items.

Between student groups, New Student pre-program scores were lower than Mentor scores for the three survey items (Analyze Data: $H(2) = 8.61$, $p = 0.01$; Develop Experiment: $H(2) = 15.3$, $p < 0.001$; Scientific Method: $H(2) = 15.1$, $p = 0.001$) (Fig. 13). Post hoc Dunn's tests showed that REMS XL students also reported lower pre-program scores than Mentors for the Develop experiment item ($p = 0.02$). There were no significant differences among post-program scores for all student groups for the survey items.

Interest

Student interest in science was assessed with eight (8) Likert-score items and one open-ended survey item (see Fig. 4). As all students express some interest in marine science during program recruitment, it was expected for interest levels to be generally high in the study population. Six (6) evaluative survey items asked New Students and Mentors to rate their interest in the modules they had experienced during the program (Fig. 14). As the REMS XL Program focused exclusively on novel research projects and thus did not include inquiry-based marine science modules, the REMS XL evaluation survey did not include these particular interest construct questions. Both New Students (average score = 4.1) and Mentors (average score = 4.0) reported high interest in the modules, and there were no significant differences in ratings among modules or between student groups.

Two (2) pre–post REMS survey items asked New Students, Mentors, and REMS XL students to rate their enthusiasm about marine science and their interest in pursuing a career in marine science (Fig. 15). Although all student groups reported generally high scores for both survey items before and after the program, New Students reported significantly higher scores for both items post-program (Enthusiasm: $U(N_{pre} = 103, N_{post} = 105) = 3909$, $z = 3.45$, $p < 0.001$; Interest in Career: $U(N_{pre} = 103, N_{post} = 105) = 3921.5$, $z = 3.13$, $p = 0.002$). There were no significant changes in Mentor or REMS XL student responses between the start and end of the program. In a comparison of scores between the two survey items, all student groups reported significantly higher enthusiasm in marine science than interest in a career in marine science before the program (New Students: $U(N_{enthusiasm} = 103, N_{career} = 103) = 2829$, $z = 2.66$, $p = 0.007$; Mentors: $U(N_{enthusiasm} = 26, N_{career} = 26) = 156.5$, $z = 2.36$, $p = 0.02$; REMS XL students: $U(N_{enthusiasm} = 12, N_{career} = 12) = 36$, $z = 2.05$, $p = 0.04$). Post-program, Mentor and REMS XL scores were similar across the two items, but New Student enthusiasm scores remained higher than interest in career scores ($U(N_{enthusiasm} = 105, N_{career} = 105) = 32{,}709.5$, $z = 2.21$, $p = 0.03$). There were no significant differences in item scores among student groups, although fewer REMS XL students seemed to indicate an intent to pursue a career in marine science post-program (Fig. 16). In response to the open-ended item asking about their intended major, the most frequently reported major was Marine Sciences before and after the program for New Students (45.9% and 57.3%) and Mentors (52.4% and 45.5%) (Fig. 17). Before the program, 36.4% of REMS XL students indicated their preference for a major in the Marine Sciences. Post-program, all REMS XL students reported an intent

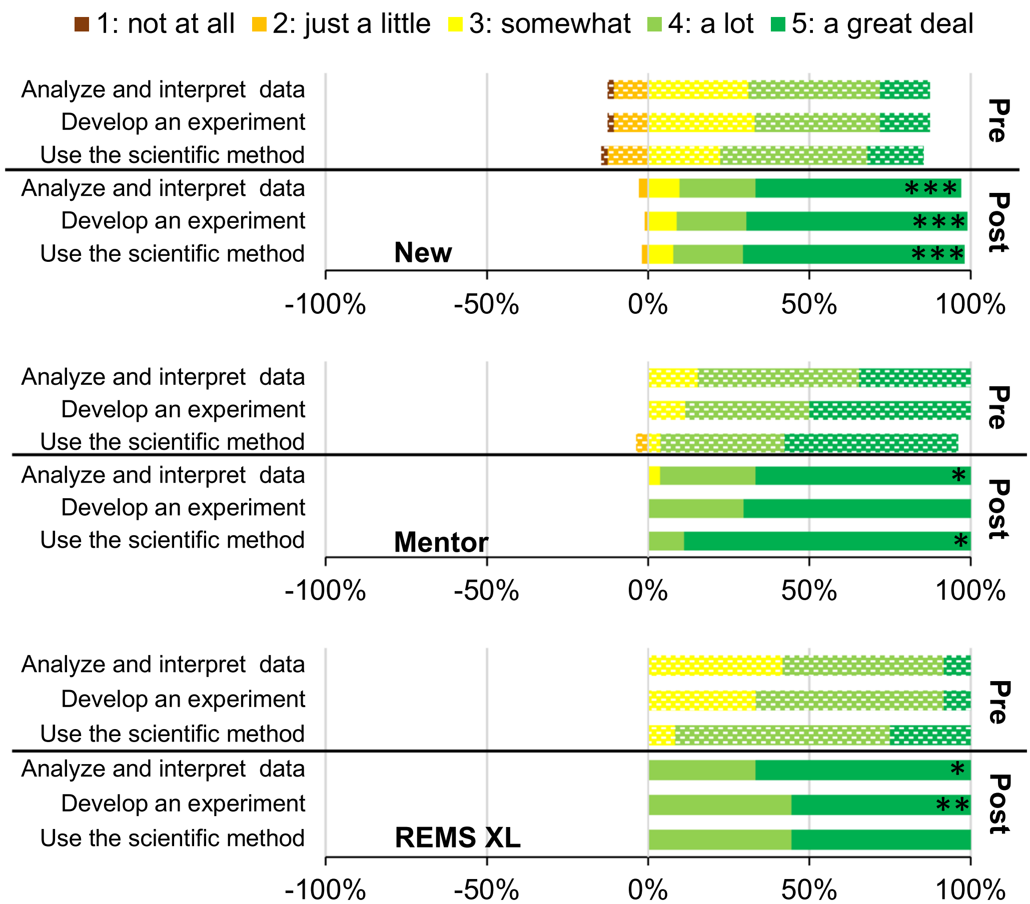

Fig. 12 Competence: Pre- and post-program student science skills competence. Responses to REMS survey science skills competence items (1 = Not at all, 5 = A great deal) collected from New Students ($N = 87$), Mentors ($N = 24$), and REMS XL students ($N = 12$). Differences in pre–post scores were analyzed with Mann–Whitney *U*-tests. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$

to pursue a STEM pathway, and 33.3% reported a Marine Science academic pathway specifically.

Recognition

The Recognition construct of science identity was assessed by analyzing six (6) Likert-score items (see Fig. 4) that asked students about confidence in their science self-efficacy, how they integrate knowledge, and the relevance of marine science. In regard to their science self-efficacy, New Students reported significant increases in their confidence of understanding marine science ($U(N_{pre} = 103, N_{post} = 105) = 2201, z = 7.89, p < 0.001$) and using the scientific method to conduct an experiment ($U(N_{pre} = 103, N_{post} = 105) = 2254, z = 7.26, p < 0.001$) (Fig. 18). Mentors only reported significant gains in their confidence of understanding marine science ($U(N_{pre} = 26, N_{post} = 25) = 205.5, z = -2.24, p = 0.03$), and REMS XL students did not report any significant changes in science self-efficacy confidence. Comparing responses between student groups with a Kruskal–Wallis test indicated significant differences in the pre-program scores for both confidence in understanding marine science ($H(2, N = 141) = 11.68, p = 0.003$) and using the scientific method (H(2, $N = 141) = 13.01, p = 0.002$) (Fig. 19). Post hoc Dunn's tests with Benjamini–Hochberg FDR adjustment showed New Student confidence in understanding marine science was significantly lower than Mentor confidence ($p = 0.002$), and New Student confidence in using the scientific method was lower than both Mentor ($p = 0.004$) and REMS XL ($p = 0.02$) confidence. There were no differences among student groups in post-program confidence scores for either item.

The next two (2) Likert-score items asked students about how well they integrate knowledge across disciplines or beyond the classroom (Fig. 20). New Students reported significant positive shifts in applying what they learn in class to other situations ($U(N_{pre} = 103, N_{post} = 105) = 3310, z = 4.83, p < 0.001$) and connecting ideas from class with other knowledge ($U(N_{pre} = 103, N_{post} = 105) = 2873, z = 5.84, p < 0.001$). Mentors

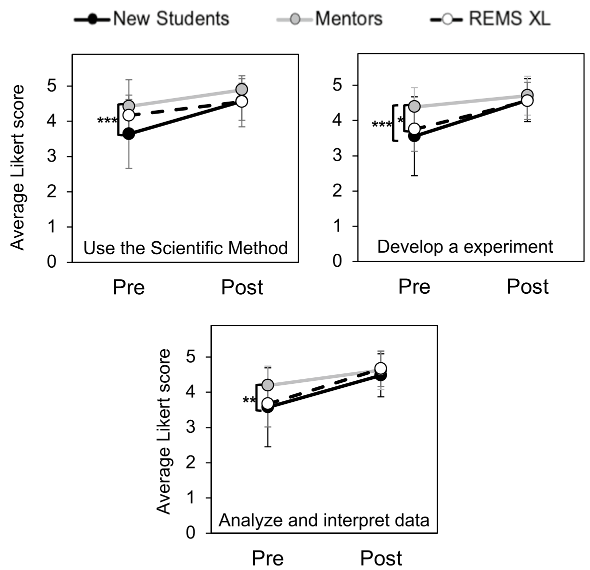

Fig. 13 Competence: Comparing science skills competence scores among student groups. Average Likert scores (1 = Not at all, 5 = A great deal) on competence REMS survey items relating to three (3) science skills collected from new students (black circle, black line; $N = 87$) and mentors (grey circle, grey line; $N = 22$) and REMS XL students (white circle, dashed line; $N = 12$). Differences in scores among student groups were analyzed with Kruskal–Wallis tests with post hoc Dunn's tests. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$

reported a significant positive shift in connecting ideas ($U(N_{pre} = 26, N_{post} = 25) = 213$, $z = -2.10$, $p = 0.04$), and REMS XL students did not report any significant shifts. As with the previous recognition items, there were significant differences between the student groups in their pre-program responses for both applying what they learn in class ($H(2, N = 141) = 13.61$, $p = 0.001$) and connecting ideas with other knowledge ($H(2, N = 141) = 9.26$, $p = 0.01$) (Fig. 21). Both New Students ($p < 0.001$) and REMS XL students ($p = 0.007$) reported lower scores than Mentors regarding applying their knowledge beyond the classroom. New Students also reported lower scores than Mentors when asked about connecting ideas with other knowledge ($p = 0.004$). By the end of the program, there were no significant differences between student group responses to these survey items.

The final two (2) items included in the Recognition construct asked students about the relevance of marine science to their lives. Once again, New Student responses to both items significantly shifted more positive by the end of the program compared with pre-program scores (Fig. 22). New Students reported a greater interest in discussing marine science with their friends or family ($U(N_{pre} = 103, N_{post} = 105) = 3581.5$, $z = 4.21$, $p < 0.001$) and agreed significantly more that ideas from the program related to their lives ($U(N_{pre} = 103, N_{post} = 105) = 2614$, $z = -6.14$, $p < 0.001$). REMS XL

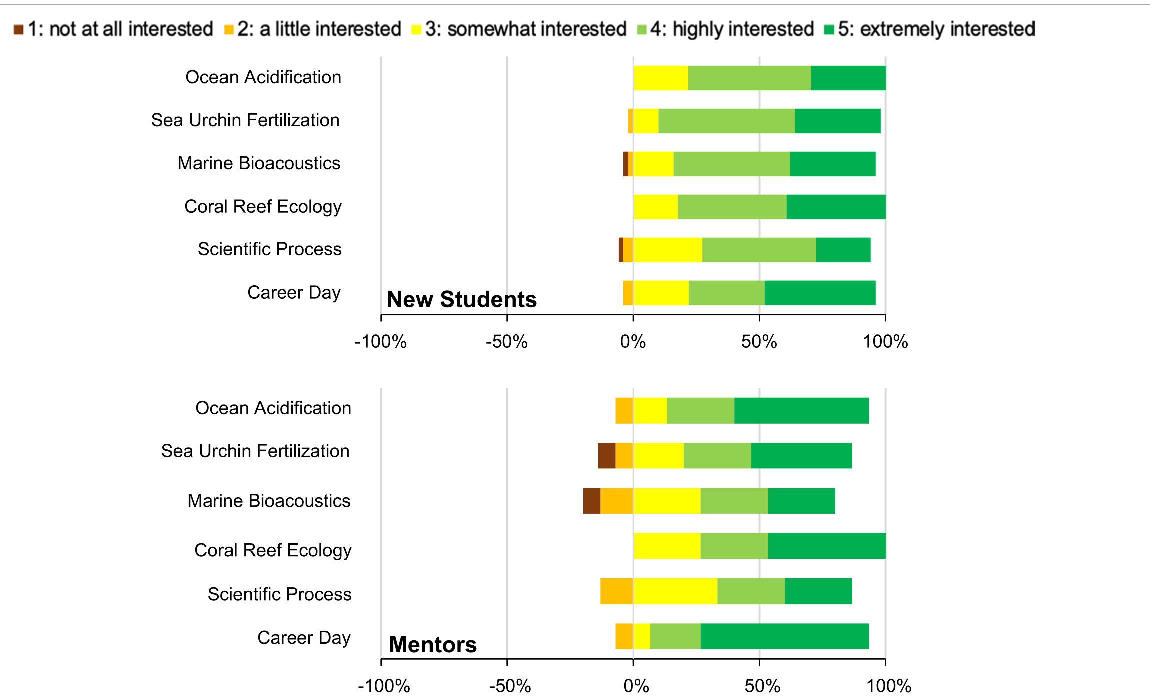

Fig. 14 Interest: Student evaluations of interest in REMS marine science modules. New Student ($N = 87$) and mentor ($N = 22$) responses to REMS survey items (1 = Not at all interested, 5 = Extremely interested) relating to interest in the marine science modules delivered during 2013–2018 REMS programs. The survey prompt for each item is: "Please rate your interest for the [module name] lecture and lab activities"

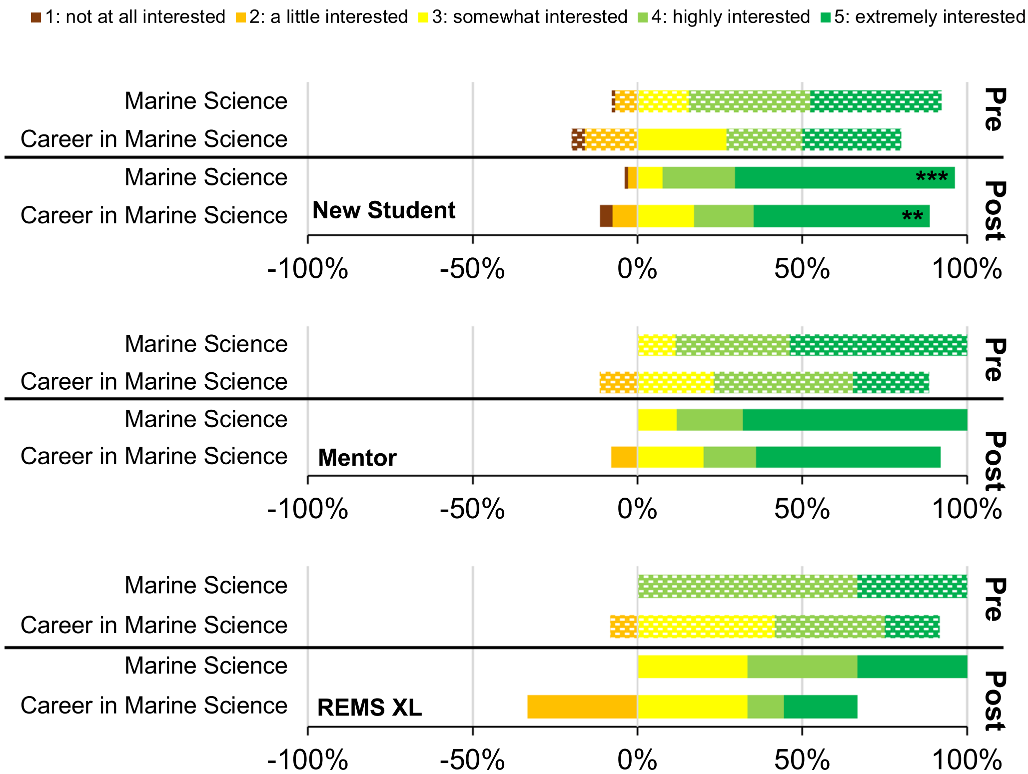

Fig. 15 Interest: Pre- and post-program student interest in marine science. New Student ($N=87$), Mentor ($N=24$), and REMS XL student ($N=12$) responses to REMS survey items (1 = Not at all interested, 5 = Extremely interested) relating to interest in marine science and marine science careers. Differences in pre–post scores were analyzed with Mann–Whitney U-tests. $^{**}p<0.01$. $^{***}p<0.001$

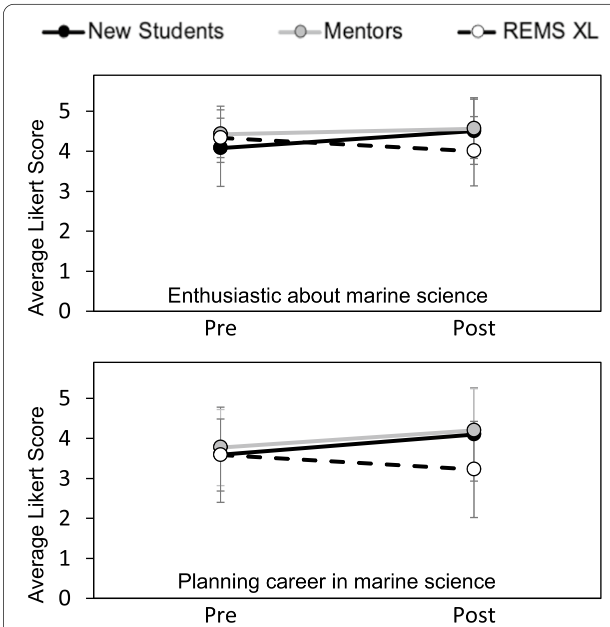

Fig. 16 Interest: Comparing marine science interest scores among student groups. Average New Student ($N=87$), Mentor ($N=24$), and REMS XL student ($N=12$) responses to REMS survey items (1 = Not at all, 5 = A great deal) relating to interest in marine science and marine science careers

students did not report any significant pre–post program shifts, but Mentors did report a significantly increased post-program understanding of how ideas from the program related to their lives ($U(N_{pre}=26, N_{post}=25)=170.5$, $z=-2.90$, $p=0.004$). Across student groups, there were no differences between New Student, Mentor, or REMS XL student pre- or post-program responses for the survey item about discussing marine science with friends and family (Fig. 23). For the item asking about understanding of how ideas from the program related to their lives, at the start of the program New Student scores were significantly lower than either Mentor ($p=0.003$) or REMS XL ($p=0.005$) responses. Post-program, there were no significant differences between New Student and REMS XL responses, but New Student scores were still significantly lower than Mentor scores ($p=0.02$).

Discussion

This study sought to examine how student science identity evolved through participation in a place-based marine science research program. Place-based pedagogical practices build upon students' personal experiences and shared cultural, historical, and political *place*. This

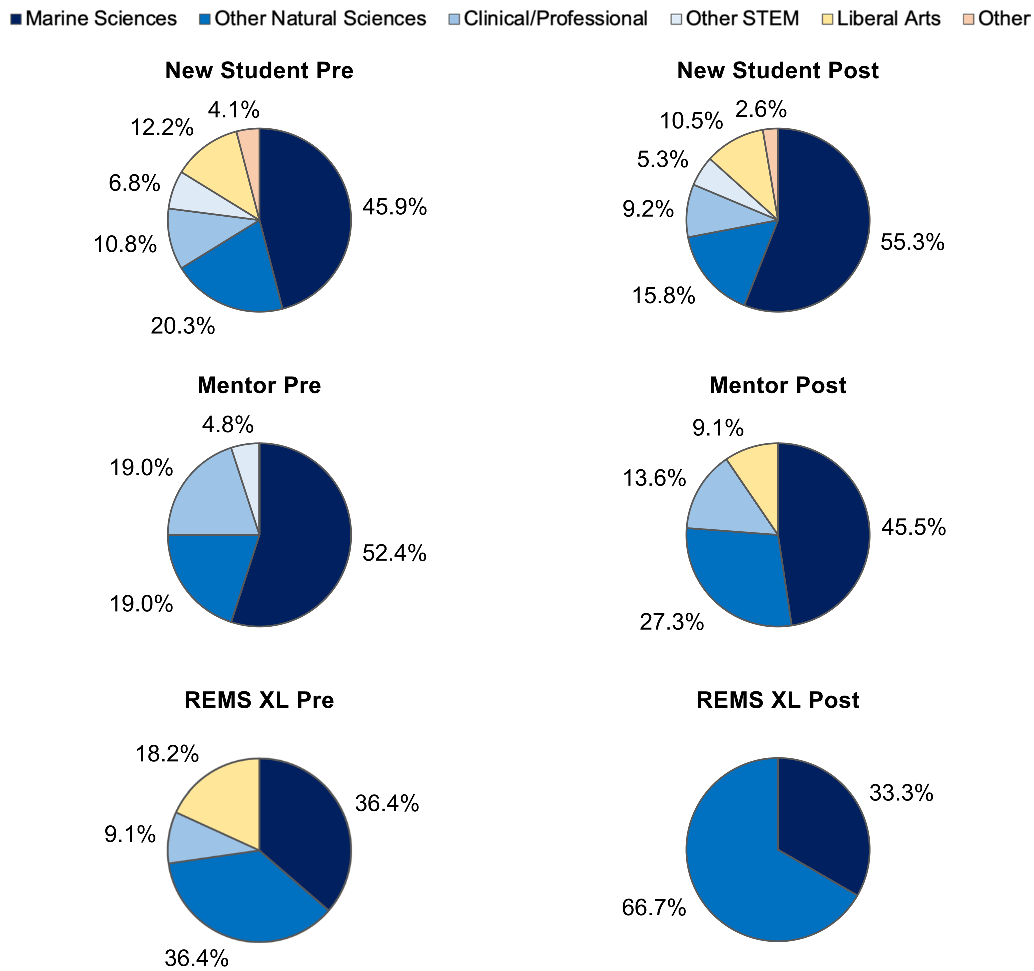

Fig. 17 Interest: Pre- and post-program student intended/reported university major. New Student ($N=106$), Mentor ($N=27$), and REMS XL student ($N=12$) responses. "Marine Sciences" includes Marine Biology, Oceanography, and other majors that are related to ocean sciences. "Clinical/Professional" majors include pre-med and pre-vet tracks. "Other Natural Sciences" includes life sciences (e.g., biology, botany) and physical sciences (e.g., physics, chemistry) that do not explicitly relate to ocean sciences

concept is important as students, especially marginalized students, who feel more connection with scientific content tend to perform better in the classroom and have more positive attitudes toward science in general (Hulleman & Harackiewicz, 2009).

The analytical framework utilized identity as a lens to examine constructs which may influence how students see themselves as a "person of science" within the scientific community. The results revealed positive post-program shifts in all three components of student science identity as described in the identity model: Performance/Competence, Interest, and Recognition.

Shifts in performance and competence

Students demonstrated positive post-program shifts in Performance (demonstrated content understanding) and Competence (reported knowledge and skill understanding). Both student groups demonstrated gains in knowledge (Fig. 5). Before the modules, both New Students and Mentors answered the fewest correct responses in the Ocean Acidification (OA) module (Fig. 6). After completing the modules, although New Students showed gains, their OA scores were still significantly lower than the other modules. Mentor OA scores were similar to scores in the other modules after completion. At the start of most modules, Mentors out-performed (i.e., answered more questions correctly) New Students (Fig. 7), and scores across student groups were similar after completing the modules. In four (4) of the five (5) modules, average New Student post-program performance scores increased to match Mentor scores. However, in the OA module student scores demonstrated a different pattern. At the start of the OA module, Mentors scored similarly to New Students. Post-module, Mentor scores

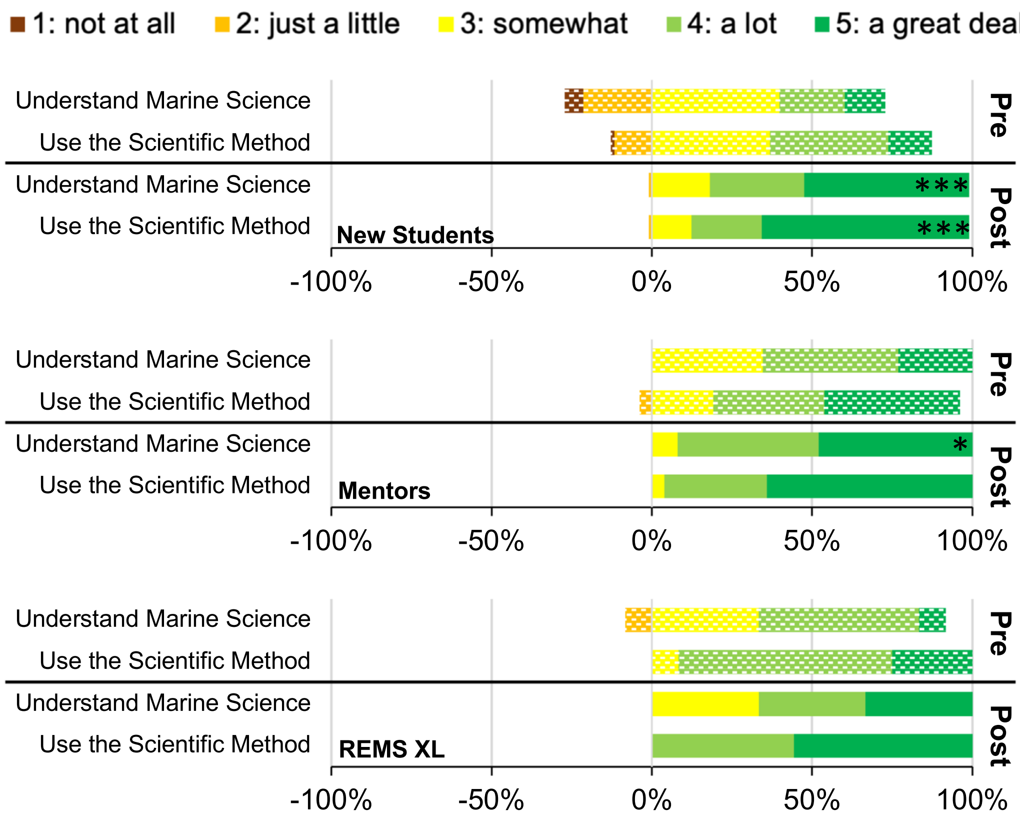

Fig. 18 Recognition: pre- and post-program recognition of self-efficacy. Student responses (New Students ($N = 105$), Mentors ($N = 26$), REMS XL (12)) to REMS survey prompts asking about confidence in their understanding of marine science and the ability to use the scientific method to conduct an experiment. Pre- and post-program differences were analyzed with a Mann–Whitney *U*-test. *$p < 0.05$. ***$p < 0.001$

were significantly higher than New Student Scores. Thus, although Mentors did not demonstrate a higher baseline understanding of OA content before the module, post-module they demonstrated greater gains in understanding than the New Students.

The performance results from the OA module are particularly interesting because the module content focuses heavily on ocean chemistry. So-called "gateway" courses are one type of academic barrier that is thought to contribute to lower rates of HEG student persistence in STEM degree programs (Pierszalowski & Bouwma-Gearhart, 2018). In the life sciences or pre-medical tracks, chemistry courses are often cited as the ultimate barrier for many students, with HEG students being disproportionately affected (Barr et al., 2008). The general positive trends in quiz results for the OA module may be explained with a well-documented phenomenon: that utilizing the spacing effect with repetition of content (i.e., repeated exposure in spaced intervals) leads to better memory (Kang, 2016). Improved learning with repetition may be due to the mediating effect of processing fluency (i.e., having been exposed to material previously, it is easier to process in repeated exposures) (Alter & Oppenheimer, 2009), but the OA module was the only module where Mentors demonstrated a larger benefit to performance. These results may indicate that educators could focus resources for repeated exposure only for specific types of content to provide the greatest benefit to students (i.e., focus on repeating more technical content, such as that found in a chemistry module).

In addition to better performance on in-class quizzes, self-reported understanding in marine science content increased for both New Students (Fig. 8) and Mentors (Fig. 9). The program seemed to impact New Student reported knowledge gains more than Mentors: New Students rated their knowledge lower before the program, but by the end of the program New Students scored their understanding just as high as Mentors (Fig. 10). There was a moderate positive correlation between module performance and competence scores suggesting that student competence and achievement were related (Fig. 11).

In written survey responses and post-survey interviews, participants indicated that the interdisciplinary nature of the place-based curriculum of the REMS and

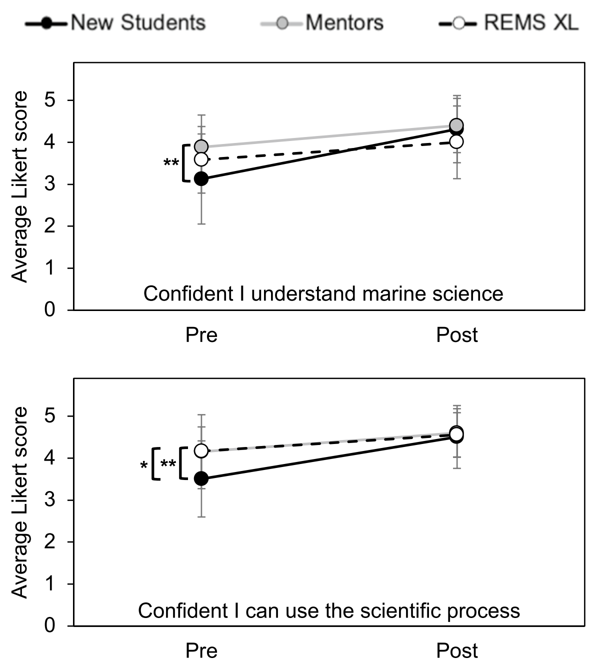

Fig. 19 Recognition: Comparing recognition of self-efficacy among student groups. Average student responses (New Students ($N=105$), Mentors ($N=26$), REMS XL (12)) to REMS survey prompts asking about confidence in their understanding of marine science and the ability to use the scientific method to conduct an experiment. Differences among student group scores were analyzed with Kruskal–Wallis tests with post hoc Dunn's tests. *$p<0.05$. **$p<0.01$

REMS XL programs helped them to see how science related to other subjects as well as other aspects of their lived experiences. Practicing science in a marine context also resonated with the students who typically spend each day in the ocean. In this interview exchange, two students discuss these themes:

Shane: I feel like what we learned here is basically like school, but everything mushed into, like, one thing that you actually enjoy. Like reading, mathematics, sciences, all into one, and it revolves around the ocean. And it's not much more better than that.
Daniela: Yeah, even history too—
Shane: Yeah, history too.
Daniela: 'Cause I kinda learned a lot about Hawaiian history which I don't know a lot of it.

There were also increases in reported competence scores for science skills for all student groups (New Students, Mentors, and REMS XL students) (Fig. 12). Similar to trends in self-assessed content understanding, New Students reported lower competence in science skills at the start of the program, but they were just as competent as Mentors by the end of the program (Fig. 13). Due to having the most cumulative research experience, it was expected that REMS XL students would report higher competence scores than New Students and Mentors. Surprisingly, REMS XL student responses often mirrored New Student averages and they reported significantly lower science skills competence ratings than Mentors at the beginning of the program as well. This decrease in reported competence might point to disruptors students face as they begin to navigate undergraduate STEM programs. There is scant Native Hawaiian representation in research examining experiences of HEG students entering or navigating post-secondary STEM degree programs, but potential disruptors for target students may include culture-shock when attending an out-of-state school, experiencing racial prejudices from professors and other students in STEM programs, or forging a path as a first-generation college student (Allaire, 2018). Imposter syndrome, a psychological state of self-doubt for performing well within a certain context or being discovered as a fraud even after demonstrated achievement, is especially prevalent among HEG students in STEM and may continue to contribute to high attrition of these demographics in college and early professional STEM communities (Chrousos & Mentis, 2020). Authentic, place-based research experiences, like those provided by the REMS program, may mitigate the effects of these barriers and bolster HEG student competence (as indicated by increased post-program competence scores for REMS XL students).

Shifts in interest

During the recruitment process for the REMS programs, applicants all indicated an interest in marine science. Both New Students and Mentors reported high interest in the marine science modules experienced during the REMS program (Fig. 14). Interestingly, students rated interest in the more difficult modules (as measured by lower quiz scores) just as positively as the other modules. New Students reported increased interest in marine science and interest in pursuing a career in marine science (Fig. 15). There were no significant differences among the reported interest levels of all student groups either pre- or post-program (Fig. 16). All student groups reported that their enthusiasm for marine science as a field was significantly greater than their interest to pursue a career in marine science. However, approximately half of the New Students and half of the Mentors declared an intent to pursue a marine science degree (Fig. 17). By the end of the program, only about one third of REMS XL students reported their major (or intended major) as marine science, but they all intended to remain in a STEM field.

Hazari et al. (2010) included Interest as a construct in their student science identity model because they postulated that interest in a subject is necessary for student

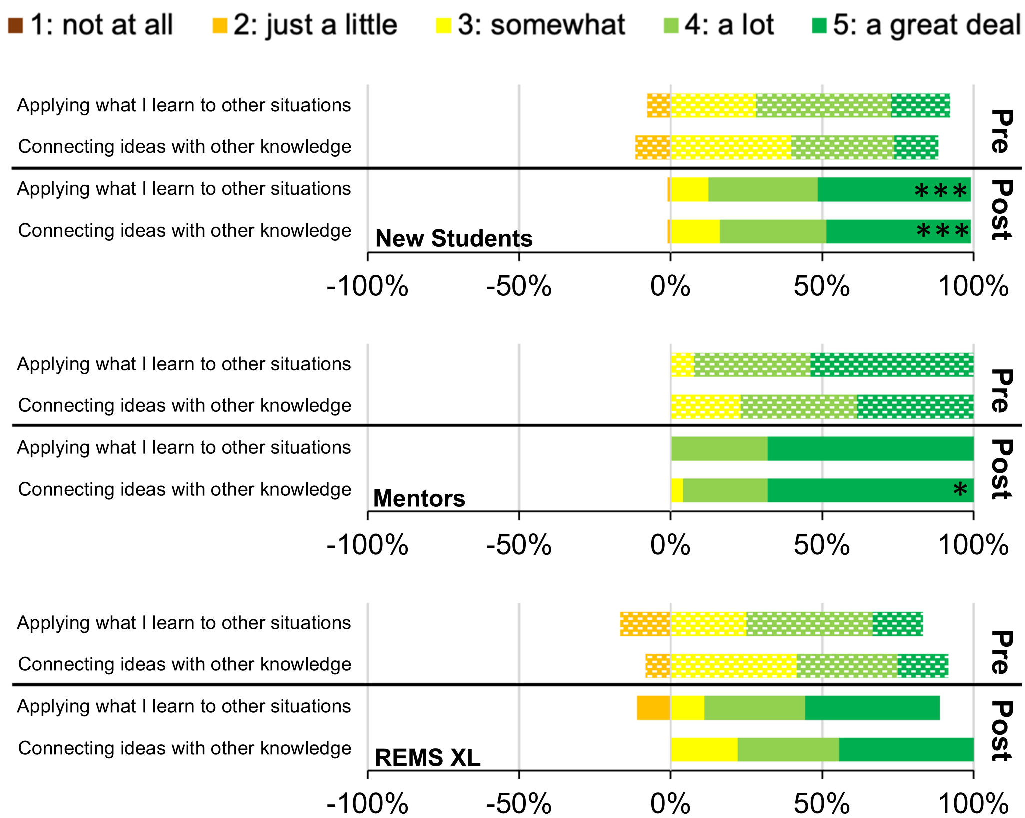

Fig. 20 Recognition: Pre- and post-program marine science use beyond the classroom. Student responses (New Students ($N=105$), Mentors ($N=26$), REMS XL (12)) to REMS survey items (1 = Not at all, 5 = A great deal) regarding how well they integrate knowledge across disciplines or beyond the classroom. Pre- and post-program differences were analyzed with a Mann–Whitney *U*-test. *$p<0.05$. ***$p<0.001$

persistence, especially for students early in their careers. The importance of interest is also echoed in psychological models for choice of a career, such as Social Cognitive Career Theory (SCCT) that includes interest as a mediator between self-efficacy and persistence (Lent et al., 1994). The Mentors and REMS XL students in this study were navigating important academic and career decisions as they transition into undergraduate programs and attempt to find their place in STEM communities. Each of the student groups reported high enthusiasm for marine science, and there was almost unanimous intention to pursue or continue in STEM pathways either through marine science or other natural science disciplines. Open-ended survey responses revealed that by the end of the program some students were still struggling with decisions regarding their future, while other students described an increased sense of direction ("Through this program this year, I learned more about myself and what I want to do for a living. I want to create a business to educate the public about their impacts we have on marine life."). Many students also reported a shift in their interest for pursuing scientific careers due to shifting perceptions of science itself ("My interests in science have change[d] as a result of this program because I actually got to feel like a scientist and meet some"; "I always disliked science because I thought it was hard and just dealt with too much numbers and that you had to be smart to like science but I realized it's really fun and theres [sic] so much more to it than just numbers and difficult words"). The responses to the interest REMS survey items hint that development of interest in marine science in and of itself is not enough to predict whether students choose a *marine science* career pathway, but the results suggest that interest in marine science could be leveraged as a way to encourage persistence in STEM fields.

It is encouraging that students found all the modules interesting, regardless of their performance on the module quizzes. When delivering the modules, both students and instructors can appear worn down at the end of the more technical modules that require prolonged periods of concentration (e.g., hours spent checking a microscope to note sea urchin zygote development). Survey responses indicating that students find these modules just as interesting as the "fun" modules (as deemed by the

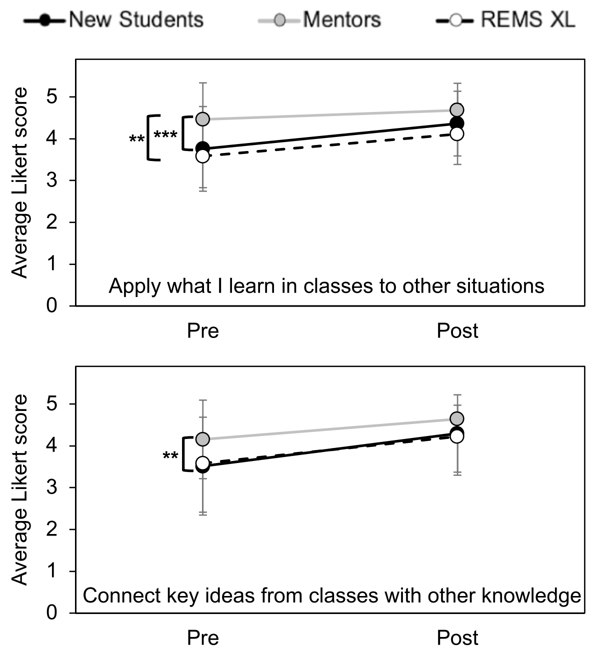

Fig. 21 Recognition: Comparing self-efficacy beyond the classroom among student groups. Average student responses (New Students ($N=105$), Mentors ($N=26$), REMS XL (12)) to REMS survey items (1 = Not at all, 5 = A great deal) regarding how well they integrate knowledge across disciplines or beyond the classroom. Differences among student group scores were analyzed with Kruskal–Wallis tests with post hoc Dunn's tests. **$p<0.01$. ***$p<0.001$

instructors—modules with charismatic animals or an in-water field component) suggest that the students enjoyed or at least appreciated challenging modules. A closer examination into the specific aspects that students found interesting or enjoyable is warranted to hone the curriculum of future iterations of the REMS program.

Shifts in recognition

The survey items used to measure shifts in the student Recognition construct fell into three groups: (a) confidence in self-efficacy (do the students recognize themselves as capable of science?) (Figs. 18 and 19), (b) integration of skills and knowledge beyond the classroom (does their self-efficacy translate to other contexts?) (Figs. 20 and 21), and (c) personal relevance of marine science (do students recognize marine science as a part of their lives?) (Figs. 22 and 23). New Students and Mentors reported significant positive increases in each of these areas after participating in the program. In written responses to post-program open-ended questions, students also reported a new recognition of how science affected their everyday lives ("I know what science really means and how it effects my life. I also know how we affect the ocean around us and how it helps us as well.").

Once again following trends seen in the other constructs when comparing responses among student groups, New Students reported lower scores than Mentors at the beginning of the program, but New Students were scoring similarly to Mentors post-program. Thus, for most metrics, New Students experienced greater gains.

Mentors and REMS XL students scored comparably high confidence in marine science self-efficacy and personal relevance of marine science. However, as also seen in the results of the competence construct, REMS XL students scored more similarly to New Students in their confidence connecting ideas and knowledge beyond the classroom. It should be noted that the two (2) recognition survey items in question did not explicitly ask about marine science or science knowledge and skills, but rather general academic knowledge and skills. Thus, the relatively lower REMS XL student responses might be reflective of their recent experiences transitioning to undergraduate learning communities. As mentioned in the previous section describing Shifts in Performance and Competence, the REMS XL students are facing new challenges that warrant further examination including potential culture-shock from attending continental US schools or experiencing curricula that are not relevant to their culture or history.

Mentors did report higher agreement than New Students pre- and post-program for one recognition item: "I understand how ideas in this class relate to my own everyday life." This is an encouraging result that persisted across time (REMS XL students also reported high agreement) and indicates the place-based aspects of the program curriculum were successful in relating the content to the students' lives. It also demonstrates that both first-time participants and alumni experience similar effect sizes in their growing recognition of the relevancy of marine science to their lived experiences. The only recognition item where New Students did not report lower agreement than Mentors or REMS XL students was "I am interested in discussing marine science with friends or family." All student groups reported similarly high levels of agreement to this survey item. It is especially important for students in target demographics to feel comfortable or encouraged to share aspects of their science identity with people the students view as important in their lives.

Recognition as a "person of science" may be one of the more powerful drivers of science identity development in HEG students (Byars-Winston et al., 2016; Carlone & Johnson, 2007; Cohen & Garcia, 2008; Kim et al., 2018; Schinske et al., 2015). This recognition is especially impactful when provided by "meaningful others", either within the science community (e.g., professors, professional researchers) or in the student's home community

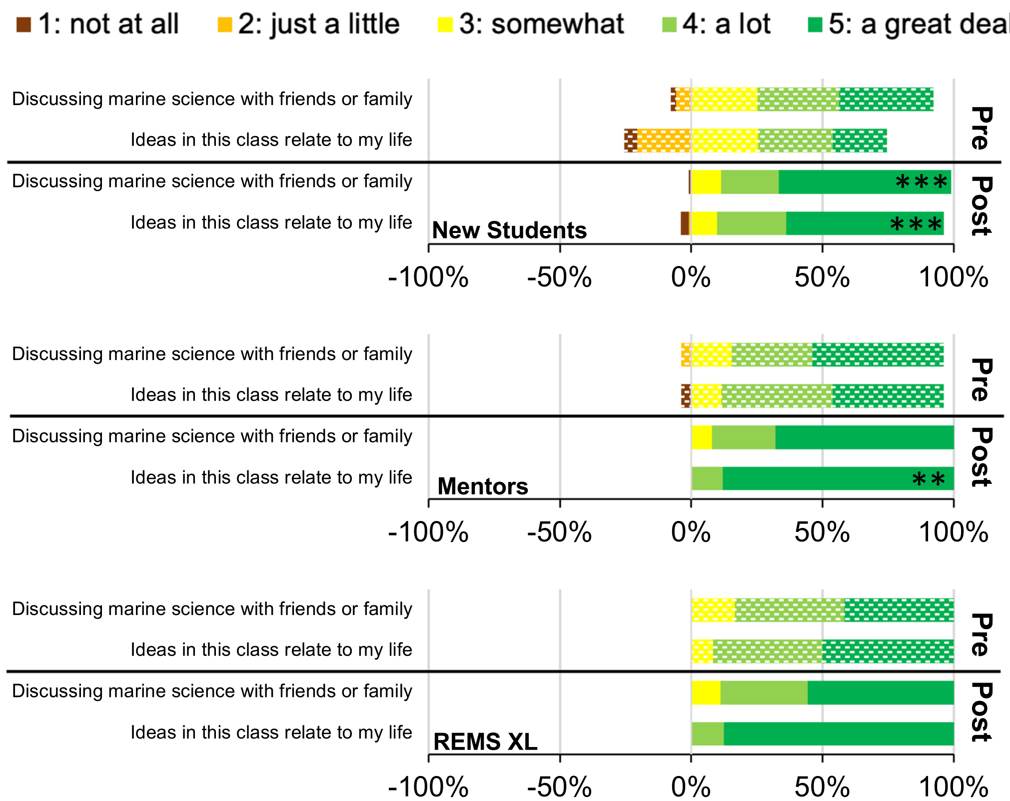

Fig. 22 Recognition: Pre- and post-program personal relevance of marine science. Student responses (New Students ($N = 105$), Mentors ($N = 26$), REMS XL (12)) to REMS survey items (1 = Not at all, 5 = A great deal) regarding relevance of marine science concepts to personal life. Pre- and post-program differences were analyzed with a Mann–Whitney *U*-test. **$p < 0.01$. ***$p < 0.001$

(e.g., parents, siblings, friends). Allaire (2018) noted through his discussions with Native Hawaiian members of Hawai'i's STEM community: "Perhaps the most critical source of support [for their identity development as Native Hawaiians and STEM professionals], came from the participants' families. [...T]he influence and support of the participants' parents and extended family cannot be understated" (p. 186). Bang and Medin (2010) also describe how the "involvement of community members [...] and the explicit use of Native epistemological orientations in science-related practices serve as a strong signal that science is not just for other people" (pg. 1019). Students in the post-program interviews discussed benefitting from being exposed to communities they might not have experienced before, or connecting with communities beyond, the ones with which they were already familiar. In connecting the science experience to their other lived experiences in the written survey responses, students described stronger personal responsibility to the marine environment ("I understand the importance of reducing the amount of trash I create and have already started to transition to reusable (instead of one-use) items"; "it has taught me that people are very oblivious to the impact we have on our world and oceans, and that we should start paying attention and making a change") and their home communities ("Because of this program, I now want to make sure that my experience and knowledge impacts my community for generations to come."). As programs are conceived and developed to nurture aspects of science identity in HEG students, it is important to remember that in many of these communities it takes more than a scientist to make a scientist.

Towards a marine science identity model for Hawai'i students

The analytical framework for student science identity used in this study was grounded in an identity model proposed by Carlone and Johnson (2007), a framework which has been adapted by other researchers to address observations from different disciplines (e.g., physics student identity (Hazari et al., 2010), chemistry identity (Hosbein & Barbera, 2020), computer science identity (Garcia et al., 2018)). In their study, which focused on the experiences of women of color in science, Carlone and Johnson (2007) found that of the three main components in their model—Performance, Competence,

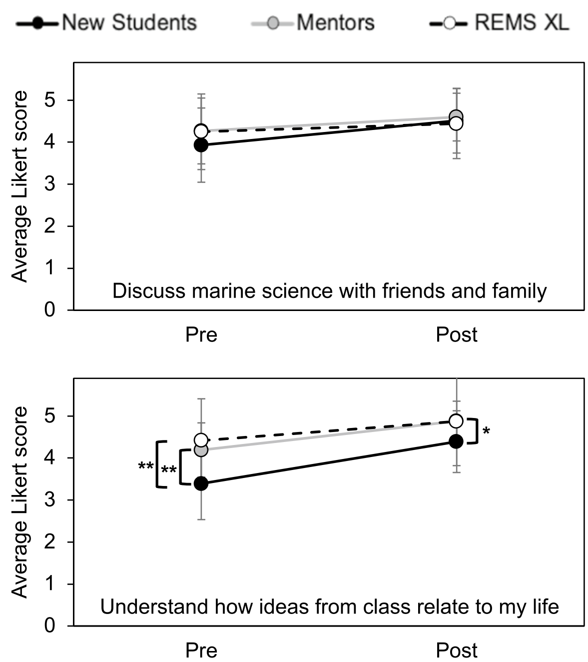

Fig. 23 Recognition: Comparing personal relevance of marine science among student groups. Average student responses (New Students ($N = 105$), Mentors ($N = 26$), REMS XL (12)) to REMS survey items (1 = Not at all, 5 = A great deal) regarding relevance of marine science concepts to personal life. Differences among student group scores were analyzed with Kruskal–Wallis tests with post hoc Dunn's tests. $^{*}p < 0.05$. $^{**}p < 0.01$

and Recognition—the critical factor was recognition, specifically recognition by meaningful others (e.g., family, respected scientists). Interest has been suggested as another construct that plays a role in the development of science identity (particularly for students or those early in their careers as a catalyst for initially entering a science field (Hazari et al., 2010), but high interest in science may not predict pathway persistence or the development of strong science identities without support from members of home and science communities (Carlone & Johnson, 2007).

In this study, New Students showed the largest shifts in items measuring constructs of science identity (i.e., Performance/Competence, Interest, and Recognition), but Mentors and REMS XL students, despite their smaller sample sizes, also showed significant shifts in their marine science identities. REMS XL student data perhaps showed some of the most interesting trends. REMS XL student pre-program scores were frequently lower than Mentor scores and similar to new Student Scores. This pattern may be attributed to the more experienced REMS XL students recognizing the complexities of navigating a new undergraduate experience and thus doubting their abilities (an example of the Dunning–Kruger effect (Kruger & Dunning, 1999)). Although not significant, REMS XL students indicated slightly decreased scores on a couple post-program items. Most notably, REMS XL students reported a (non-significant) decrease in interest in a career in marine science. However, this might be attributed to developing interest in other STEM pathways as the students become more familiar with tangential fields through the REMS program or university programs. Thus, the students were not simply losing interest in marine science, but instead refining their interest in the general STEM community (as indicated by the REMS XL students who all indicated a desire to pursue marine science or STEM pathways by the end of the program). Future work is needed to examine whether this interpretation explains the student responses and to explore reasons why the students valued the field of marine science but indicated preference for different STEM career pathways.

Conclusions

This study sought to examine whether the constructs of student science identity shifted for participants in a Hawai‘i place-based marine science CURE and whether recurrent exposure to the curriculum continued to nurture the development of the aspects of science identity. In summary, the results demonstrate that all three constructs of science identity (Performance/Competence, Interest, and Recognition) were strengthened after participation in the REMS and REMS XL programs. All student groups reported positive shifts in science identity constructs, but New Students reported the most significant changes. Pre-program, Mentors (late-high school through early undergraduate age) reported higher scores than New Students in most items. REMS XL students (early to mid-undergraduate age) scored more similarly to New Students in pre-program responses, but had "recovered" to match Mentor scores by the end of the program. On several of the survey items, the REMS XL student data also indicated unique response patterns that warrant further investigation (coupled with larger sample sizes) into potential student marine science identity development.

Place-based pedagogies are especially important in developing more inclusive science learning experiences, and HEG students who enter undergraduate programs with a stronger view of science as culturally relevant to issues in their home communities develop greater science identity over time (Jackson et al., 2016). CUREs developed and delivered within place-based frameworks may thus provide an environment to foster HEG student persistence in STEM. The Research Experiences in Marine Science Summer Program illustrates how content and practices that are relevant and respectful of student experiences beyond the classroom can foster positive student development in student groups historically marginalized in the science community.

Abbreviations
HEG: Historically excluded group; PBE: Place-based education; CURE: Course-based undergraduate research experience; REMS: Research Experiences in Marine Science; REMS XL: Research Experiences in Marine Science Excel; STEM: Science, technology, engineering, and mathematics.

Acknowledgements
We would like to acknowledge the invaluable instructors, collaborators, staff and other supporters of REMS, especially Mackenzie Manning, Sherril Leon Soon, Yoshimi Rii, Jeremy Soriano, Alexi Meltel, Hoaka Thomas, and Seaenna Correa-Garcia. We are also grateful for thoughtful comments and guidance on early drafts from Margie Maaka, Laiana Wong, Summer Maunakea, Matthew Medeiros, and Kekailoa Perry. The REMS Program was generously supported by the Hau'oli Mau Loa Foundation. We also sincerely thank the students of REMS for allowing us to share in their experiences.

Author contributions
CMA led the study. CMA worked closely with other partners to conceptualize the project and then led participant recruitment; data collection, cleaning, and curation; data analysis and interpretation; manuscript drafting; and manuscript revisions and editing. MAJR contributed to the conceptualization of the project and assisted with participant recruitment; data collection and interpretation; and extensive revisions and comments on the manuscript. Both authors read and approved the final manuscript.

Funding
Research presented in this study was supported by the STAR Achievement Scholarship, and the UHM COE General Scholarship.

Availability of data and materials
The datasets generated and/or analyzed during the current study are not publicly available due to the potential to indirectly identify individual study participants based on a combination of demographic characteristics and location data. However, select subsets of data are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare they have no competing interests.

Received: 19 April 2022 Accepted: 28 October 2022
Published online: 23 November 2022

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